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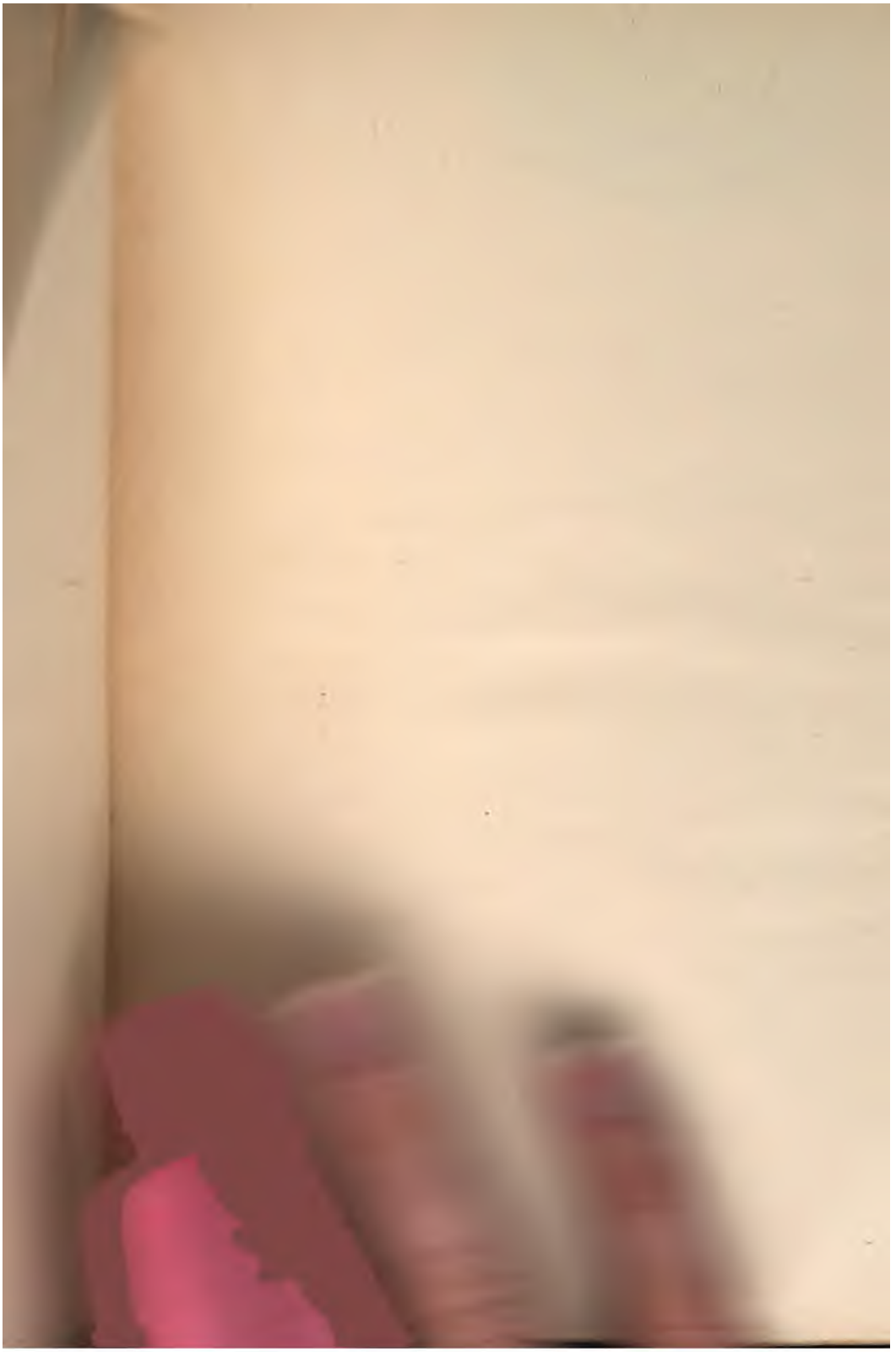
The MARVELS of MODERN MECHANISM



COTTON PICKERS.

THE

Marvels of Modern Mechanism

AND

THEIR RELATION TO

SOCIAL BETTERMENT

BY

JEROME BRUCE CRABTREE

Author of "The Passing of Spain"

With Special Chapters by

CARROLL D. WRIGHT, LL.D.

AND

WILLARD SMITH, M.D.

"What yesterday I should have declared impossible, I have to-day seen realized."

—LORD KELVIN

THE KING-RICHARDSON COMPANY

SPRINGFIELD, MASS.

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1901

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PREFATORY.

THIS work is an attempt to describe in language free from technicalities a few of the most striking inventions and to show what part they have played in our industrial life. It is not a technical treatise but is rather a tribute to the men who have "thought in iron and steel" and an attempt to show how their work has benefited society.

The demands of modern life are so exacting that the average man is prone to forget how much he owes to those who have helped to bring civilization out of savagery. This book is issued in the belief that he is unthoughtful rather than ungrateful and that he will be glad to have their struggles and victories recalled to him.

It has been the writer's good fortune to add to the value of the book by the special articles contributed by Hon. Carroll D. Wright and Willard Smith, M.D. Recognition is made of the painstaking work of Heber A. Hopkins, B.S., in reading the technical parts of the manuscript.

Thanks are due to Colonel J. P. Farley and other courteous officers of the Ordnance Department for information furnished; to the Bethlehem Steel Co., R. Hoe and Co., the Westinghouse Air Brake Co., the Commercial Cable Co., the Baldwin Locomotive Works, and many other progressive manufacturers for literature descriptive and cuts illustrative of their work.

JEROME BRUCE CRABTREE.

SPRINGFIELD, MASS., April, 1901.

LIST OF AUTHORITIES.

THAT this work might be as nearly accurate as possible, constant reference has been made to the highest available authorities. That it might speak of the latest achievements, a large number of technical periodicals have been consulted. The following list will have some interest for the general reader and will be of considerable value to the student who desires to pursue the subject more fully.

BOOKS CONSULTED.

Alaska. Published by the Bureau of American Republics. 1897. Washington.
American Telegraphy. Maver. New York. 1897.
A Manual of the Steam Engine. R. H. Thurston (Cornell). New York. 1894.
Articles by Maxim, Chanute, and Holland.
Boilers and Furnaces. Barr. Philadelphia. 1898.
British Locomotives. C. J. Bowen Cooke. London.
Business Openings for Girls. White. Boston. 1891.
Chambers's Encyclopædia. Philadelphia.
College Training for Women. Claghorn. New York. 1897.
Compendium of Transportation Theories. McCain. Washington.
Electricity One Hundred Years Ago and To-day. Houston. New York.
Encyclopædia Britannica. New York.
Entomology. Packard. New York. 1898.
Fatigue of Metal in Wrought Iron and Steel Forgings. Porter. Philadelphia.
Guide to the Yukon Gold Fields. Wilson. Seattle. 1897.
Helps for Ambitious Boys. Drysdale. New York. 1899.
High Office Buildings. Birkmire. New York.
History of Paper. J. E. A. Smith. New York.
History of the Baldwin Locomotive Works. Philadelphia.
History of Pennsylvania. Eagle. Philadelphia.
History of Steam Navigation. Rear Admiral Preble, U. S. N. Philadelphia.
History Studies of Johns Hopkins University. Baltimore.
Industrial History of the United States and Canada. Bolles. Norwich, Ct. 1879.
Influence of Sea Power upon History. Capt. A. T. Mahan. Boston. 1892.
Influence of Sea Power upon the French Revolution and Empire. Boston. 1892.
Information from Abroad. Publication of Naval Intelligence Office. Washington.
Iron in All Ages. Swank. Philadelphia.
Journalism for Women. E. A Bennett. London. 1898.

Lecture of Charles E. Tripler.
Life of Cyrus W. Field. Harper's. 1896. New York.
Literature furnished by numerous manufacturers.
Manitoba. Macoun. New York. 1883.
Michigan Board of Health Report. Detroit. 1895.
Modern Mechanism. Appleton. New York.
Modern Methods of Sewage Disposal. George E. Waring. New York. 1894.
Naval Annual. '92, '93, '94, '95, '96, '97, '98. Lord T. A. Brassey. London.
Newfoundland to Manitoba. W. Fraser Rae. New York. 1881.
Nickel Steel for Crank, Pins, and Axles. Porter. Philadelphia.
Official Handbook of Information Relating to the Dominion of Canada. Government Publication. 1893. Ottawa.
Ordnance and Gunnery. Bruff. New York.
Original Article. Frederick E. Ives, Inventor of Kromscop.
Physical Development and Exercise for Women. Bissell. New York. 1891.
Physics. Barker. New York.
Photography. Abney. New York.
Pleasant ways in Science. Proctor. London.
Poor's Manual of the Railroads of the United States. New York.
Practical Paper Making. Clapperton. New York.
Problems of Greater Britain. Dilke. London. 1890.
Proceedings of the United States Naval Institute. Annapolis.
Ready for Business, or Choosing an Occupation. Manson. New York. 1889.
Reports of the United States Geological Survey. Washington.
Report of Committee of Transportation of the American Economic Association. New York.
Report of John W. McCain, President of Commercial Cable Co. New York. 1895.
Reports of the United States National Museum. Washington.
Recent Economic Changes. David A. Wells. New York. 1891.
Senate Report. 1142. 52d Congress. Washington.
Separate System of Sewage. Cady Staley. New York.
Sewage Disposal in the United States. Rafter & Barker. New York.
Sewage Disposal. Kiersted. New York. 1893.
State Department Documents. Washington.
Steam Engine. London. Burns.
Steel Construction. Purdy. Madison, Wis.
Steel for Marine Engines and Shafting. Davenport. Philadelphia.
The Century of Electricity. Mendenhall. Boston.
The Electric Automobile. Woods. Chicago.
The Health of Nations. Edward Chadwick. London. 1897.
The Gatlings at Santiago. Parker. New York. 1899.
The Life and Work of Cyrus W. Field. Isabella Field Judson. New York.
The Laying of the Atlantic Cable. Henry O'Neil. Edinburgh.
The Atlantic Telegraph. W. H. Russell. London.
The Telephone. Du Moncel. New York.
The Story of a Piece of Coal. Martin. New York.

The Student's Cotton Spinning. James Nasmith. Manchester.
The Textile Industries of the United States. Bagnall. Cambridge.
The Quarter Century in Photography. Wilson. New York.
The Queen's Highway. Cumberland. London. 1887.
The Story of Photography. Story. New York.
The World's Railways. J. G. Pangborn. New York.
The Development of Transportation System in the United States. J. L. Ringwalt. Philadelphia.
The Report of the United States Government Deep Waterways Commission. Washington.
The Training of Girls for Work. Edith A. Barnett. New York. 1894.
The Woman's Book. 2 Vols. New York. 1894.
The World's Congress of Representative Women. Edited by May W. Sewall. Chicago. 1894.
Through the Gold Fields of Alaska to Behring Straits. De Windt. New York. 1898.
Thrown on Her Own Resources, or What Girls Can Do. Mrs. J. C. Croly. New York 1891.
Triumphs of Modern Engineering. London.
Treatise on Electricity and Magnetism. Gordon. New York.
Treatise on Wooden Trestle Bridges. Foster. New York.
United States Patent Office Reports. Washington.
Wages, Prices and Cost of Living. Carroll D. Wright. Boston.
Water Purification. Rideal. Philadelphia. 1897.
Water Supply. Mason. New York. 1896.
Wireless Telegraphy. Kerr. New York. 1898.
Westinghouse Air Brake Co.'s Instruction Book. Pittsburgh.
What Shall we do with our Daughters? Mary A. Livermore. Boston. 1893.
What Shall our Boys do for a Living? Wingate. New York. 1899.
What Women can earn. New York. 1899.
Wonders of Modern Mechanism. Cochrane. Philadelphia.
Women and Economics. Charlotte Perkins Stetson. Boston. 1899.
Work for Women. Manson. New York.
Women in the Pulpit. Frances E. Willard. Boston. 1888.
Women in the Business World. By One of Them. Boston. 1894.

TECHNICAL PERIODICALS CONSULTED.

American Architect. Boston.
American Manufacturer and Iron World. Pittsburg.
American Journal of Science. New Haven.
Annals of the American Academy of Political and Social Science. Philadelphia. 1893.
Army and Navy Journal. New York.
Automobile Magazine. New York.
Bulletin American Iron and Steel Association. Philadelphia.
Canadian Engineer. Montreal.

Cassier. New York.
Consular Reports. Washington.
Electrical World and Engineer. New York.
Engineer. London.
Engineering. London.
Engineering Magazine. London.
Engineering and Mining Journal. New York.
Iron Age. New York.
Iron and Coal Trades Review. London.
Journal of United States Artillery. Radford. New York.
Journal of United States Artillery. Fort Monroe.
Machinery. New York.
Marine Engineering. New York.
Science. New York.
Scientific American. New York.
United Service Magazine. London.

OTHER PERIODICALS CONSULTED.

Arena. New York.
Belford's Magazine. London.
Canadian Magazine. Toronto.
Century Magazine. New York.
Chambers's Journal. London.
Chautauquan. Meadville.
Cosmopolitan. New York.
Daily Advertiser. Boston.
Daily Graphic. London.
Education. Boston.
Edinburgh Review. Edinburgh.
Fortnightly Review. London.
Forum. New York.
Good Words. London.
Harper's Magazine. New York.
Lippincott's Magazine. Philadelphia.
Living Age. Boston.
Marine Engineering. New York.
McClure's Magazine. New York.
Munsey. New York.
Nation. New York.
National Review. London.
Nature. New York.
New England Magazine. Boston.
New Review. London.

Nineteenth Century. New York.
North American Review. New York.
Popular Science Monthly. New York.
Public Opinion. New York.
Quarterly Review. London.
Review of Reviews. London.
Scribner's Magazine. New York.
Spectator. London.
Strand. London.
The Empire. Toronto.
Tribune. New York.
Westminster Review. London.

INTRODUCTION.

A LIFETIME would be too short for the ablest writer to do full justice to the debt civilization owes to the inventive genius which has evolved the marvelous machinery of our time from the rude stone implements of an age of savagery. Familiarity with these achievements seems to have lessened general appreciation of the great progress that has been made, even within the century just closed.

The world thrills at the recital of the deeds of a Livingstone, a Stanley, or a Nansen, those intrepid explorers of the unknown regions of "Darkest Africa" and the frozen North. Surely those other explorers who invaded an equally unknown realm of natural law and physical forces, who have enabled us to substitute comfortable clothing for the skins of wild beasts, who have given us warm, lighted, and happy homes in exchange for the cave of the savage, cold, dark, and reeking with moisture, who have made it possible to heap our breakfast tables with the choicest food products of a dozen countries, who have given us quick and easy communications with our loved ones at a distance, whose discoveries have eradicated some diseases and rendered all others less terrible; who, in short, have made our lives full, rich, and worth living, are entitled to some evidence of our appreciation.

Society accepts these benefits as unconcernedly as though they had always existed, but they have been bought at the expense not only of toil, but often of privation, suffering, and ruin. Frequently have the lives of inventors been threatened and their property destroyed by the people who had most to gain by their inventions. Often they have been dead and forgotten before the world was suffi-

ciently advanced to make use of their discoveries. Who were these inventors and how has all this progress been gained?

Lying off the northeastern coast of Australia is a coral reef more than 1200 miles in length, the work of countless myriads of microscopic animals. Only the upper part of the reef is alive, and it has for a foundation, the work of previous colonies that have lived, died, and bequeathed their hard, stony skeletons as a legacy to succeeding builders. The identity of the earlier workers is hopelessly lost, but the fragments of their skeletons are a necessary part of the reef's foundation and from them many a parallel illustrating the growth of society can be drawn. For, like the building of the coral reef, each invention is based upon the data collected by society from all the ages, and the inventor consciously or unconsciously avails himself of the experiences of those who have lost their identity as completely as the countless numbers forming the foundation of the coral reef. It is an accepted belief having in psychology almost the force of a law, that any mental picture, no matter how strange, must be built upon data at some other time collected by the individual. If it is psychologically true that one cannot even dream of something of which he has never heard, it is equally true that all great inventions are based upon the acquired sum of human knowledge.

The man who first subjugated fire and enslaved it for the service of mankind was as great a benefactor of his race as any subsequent discoverer or inventor.

The primitive man was at war with all the rude forces of nature, the beasts of the forests, and his hardly less savage fellows. Each improvement in his weapons placed a premium on intelligence, rendered brute force less decisive, and raised him higher in the scale. The man who hit upon metal as a substitute for stone added immensely to the sum of human knowledge. The discovery made him a better builder, a more successful hunter, a much more dreaded

antagonist. In tribal conflicts where the metal weapon of the one clashed against the stone weapon of the other, victory must have fallen to the more intelligent.

All the wants of the primitive man were supplied by his own efforts; he built his own house, hunted wild beasts, used their flesh for food and their skin for garments. The development of tribal organization brought out various abilities; one man became a fisher, another a hunter, a third a maker of weapons. Each took upon himself the part he could best perform and this division of labor marked one of the most important epochs in the history of man, for it was the parent germ of "the factory system" with all that signifies. Specialized labor became more skillful, made better pottery, turned out better tools, better weapons, and built better dwellings.

One of the most marvelous features of modern civilization is the snail-like pace with which it began and the astonishing rapidity with which it is now progressing. Professor Flinders Petrie ascribes an age of at least 100,000 years to the first rude flints found in the Kentish hills of England and an age of 10,000 years to the polished flint weapons made when man was beginning to engage himself with pastoral and agricultural pursuits. If the estimate is correct it took 90,000 years for him to pass from a dweller in caves and a user of the roughest stone weapons to a builder of rude dwellings and a maker of polished stone weapons. In the latter age he made pottery and spun and wove a rude kind of cloth. For his defense he constructed earthworks so large as to suggest a tribal organization.

The Cave Dwellers inhabited large caves of Western Europe, especially those of England, Belgium, and France. Accumulations from their kitchens and workshops mixed with falling material from their walls have in the course of time built up layers many feet in thickness which, like the pages of a book, contain a history of their progress. The cave man lived in the days of the saber-toothed tiger

and the hairy mammoth. He made needles and awls of bone, from which we conclude he made clothing. He made ornaments from the teeth of animals and was something of an artist, for he often traced on bones or the walls of his cave outlines of men or animals, and his pictures of the hairy mammoth with its long mane, curved tusks, and hanging trunk show considerable skill.

The Lake Dweller was a later and higher type of man. He associated with his fellows, built his house on piles over a lake, and had a home easily defended from enemies without and a constant supply of food and drink underneath. Such settlements were first found in the Swiss lakes but they are now known to have existed in France, Hungary, Italy, Holland, and the British Isles. Many such villages have been explored, some of which were built on no less than 100,000 piles set upright in the water and fastened by cross-beams pinned together. This mode of life lasted for thousands of years and passed from the use of stone tools to those of bronze. The lake dweller was a *round headed* man; he cultivated flax, grapes, and grain; made pottery and ornamented it; kept several domestic animals, and the pictures he left show that he yoked cattle to the plow.

The *long headed man* of the bronze age improved upon the work of his predecessors. He used copper and perhaps hardened it, but when he mixed tin with copper and invented bronze, he was able to produce tools and weapons that materially improved his own condition. It is believed that man passed from stone to bronze tools in about 5000 years. Bronze was freely used in Egypt 3000 years B. C., and iron about 1500 B. C., though it was earlier known to the Babylonians; it reached Italy about 700 B. C., and Britain about 400 B. C., and its use accelerated the progress of the race.

The oldest man in America was found beneath the great lava beds of California, where the rivers have cut through from 2000 to

4000 feet of lava rock, an operation that must have required thousands of years for its performance. However it was the valleys of the Nile and the Euphrates that witnessed the dawn of history and there is found the earliest trace of civilized man.

The earliest Egyptians were of a race resembling the inhabitants of southern Europe, but about 5000 to 6000 B. C. Egypt was invaded by Asiatics having a better knowledge of metals and better weapons. The invaders overthrew the government, coalesced with the natives and formed a very able race. The new Egypt reared great buildings requiring accurate workmanship, undertook extensive public works, showing they understood the art of organizing labor. They anticipated the Suez Canal by three times connecting the Nile with the Red Sea and from 1500 B. C. to 1200 B. C. Egyptian ships traded all along the coast of the Mediterranean. They were workers of metals; cultivated and spun flax and perhaps cotton; made paper from papyrus; had an extensive literature and believed in the immortality of the soul.

When Abraham left "Ur of the Chaldees" in the valley of the Euphrates, 2000 B. C., he left an old, rich, highly civilized, and thickly populated country, one that had not only a language but a literature, and had possessed the art of writing for thousands of years. Here were located the famous cities of Babylon, Nineveh, Accad, Nippur, and, perhaps others as great that are now forgotten. Large libraries were established containing dictionaries in which words were defined in three languages arranged in parallel columns. They erected magnificent temples, cultivated art, and had an elaborate system of laws.

It is commonly supposed these ancient civilizations had no effect upon the intellectual life of Europe. Excavations in Greece prove that country was engaged in commerce with Egypt 1000 years B. C. Psammetichus I. (666-612 B. C.) employed Greek mercenaries to assist

him in his wars and "occasioned the first grand impulse in the intellectual life of Europe by opening the ports of Egypt and making that country accessible to the blue-eyed and red-haired barbarians of the North. It is scarcely possible to exaggerate the influence of this event upon the progress of Europe." This was 300 years before Alexandria was founded. Babylonian influence is even more strongly marked; it has given astronomy the signs of the Zodiac, the months of the year, seven days in a week, the division of circles into degrees, and has left its imprint on the religion of the Hebrews. Professor Petrie says that the Greek character and growth of fine arts, 700 B. C., was largely influenced by the Assyrian and Egyptian work at second hand, obtained through the Greek settlements.

The decay of these ancient civilizations was coincident with the intellectual development of Greece and Rome, and when the gloom of the dark ages that had swept over Europe lifted, the scene of the greatest industrial activity was found in Belgium and the Netherlands. No very considerable progress had been made, but each advancement was due to discovery or invention, as that of the mariner's compass, the use of gunpowder in warfare, or the art of printing from movable types. With the discoveries of Newcomen and Watt the scene of activity shifted to England, and the resulting development will be treated at length in the body of this work.

The steam engine caused an industrial and intellectual revolution, totally changed man's mode of existence, and wrought an astonishing improvement in his condition. When the locomotive succeeded the wagon and the plodding caravan, the world shrunk at a bound to one twentieth its size, and man was able to do in a day more than he could formerly accomplish in a year. Every improvement that lightened his toil and made the struggle for food, clothing, and shelter easier, was followed by increased activity in his intellectual life. There can be little display of exalted sentiments where man is

struggling desperately to preserve a precarious existence, but as invention improved his physical and intellectual condition his moral growth was quickened. He founded hospitals, orphan asylums, and libraries; recognizing in ignorance the greatest foe to progress he established free schools. The increase of human happiness is a true test of human progress. The insane, once believed to be possessed of the devil and treated with shocking barbarity, now receive uniform kindness and skilled attendance. Sanitary engineering has rendered impossible loathsome plagues that once swept over Europe and wiped out whole villages and cities. Even war has been divested of half its horrors. Cromwell led an assault on Drogheda and says, "We put to the sword the whole number of the defendants." Nearly 1000 who had taken refuge in a great church were killed, yet Cromwell was not more merciless than the times, and prisoners taken in any battle were likely to be sold as galley slaves. The Spanish soldiers of the Spanish-American war were sent home at the expense of their captors. Criminals are no longer confined in prisons too horrible for description, but now enjoy more physical comforts and educational advantages than did the laborer of the eighteenth century. At Sing Sing the convicts are permitted to attend school, Bible classes, and prayer meetings. They have the right to see the physician at any time and have freely at their service medical skill that could not be secured by the most powerful monarch of Christendom 100 years ago. The progress made in medicine and surgery has wonderfully relieved human misery and added thousands of years to the life of each generation. It is an open secret in the medical profession that the life of Washington might have been prolonged by a simple operation which thousands of physicians are now capable of performing, and the first man of the nation died for the lack of skill which is now freely available for the meanest pauper in any great city.

"Who is it would sigh for the days that are gone?"

MODERN MACHINERY

AND ITS BENEFITS TO MANKIND.

By Carroll D. Wright, LL.D.

Textile Machinery — The Factory System — The Cotton Gin — Illuminating Gas — Steam and Electricity — Street Cars — Elevators — Clothing — Sewing Machines — Typewriter — Anæsthetics — Agricultural Machinery — Printing — Influence of the Printing Press — How Machinery Affects Labor.

Textile Machinery. Since the Christian era no event has occurred having such important effects upon the interests of mankind at large as the invention of printing with movable types; and since that invention the institution of the factory system, resulting from the inventions of machinery used in the manufacture of textiles, must be considered as the most important. These inventions belong to modern times; they were for spinning and weaving machinery, and were developed to great extent during the last third of the eighteenth century. Practically, the decade of years from 1760 to 1770 can be considered as the birth of these inventions. The application of steam as motive power in the use of machinery supplemented the utility of the spinning and weaving devices by allowing power other than water to be applied to their working. The modern system of labor can well be called the factory system, because it is only through the use of machinery and a motive power that can be

utilized at any point that the factory system finds its vital force. All inventions, therefore, which relate to the production of goods by machinery through the application of power, whether water, steam, or electricity, belong to that system, and this, as already stated, is entirely modern.

Factory System versus the Sweating System. The factory system has been of immense power as a civilizing agent in the world. Prior to its existence all goods were produced by the slow, tedious hand methods, which constituted the sweating system as we know it to-day. When we find the sweating system in any of the great cities it is simply the lingering remains of the universal system which preceded the establishment of the factory. The factory itself must be understood in order to comprehend its great influence on human welfare. It is scientific in its nature; even in its structure its parts must be harmonious, the calculations requisite for their harmony involving the highest mathematical skill. Under the system which it typifies the combined operation of many orders of work people is secured in operating with assiduous skill a series of productive machines continuously impelled by a central power. According to Dr. Andrew Ure, the factory, in the strictest sense, involves the idea of a vast automaton, composed of various mechanical and intellectual organs, acting in uninterrupted concert for the production of a common object, all of them being subordinated to a self-regulated moving force. Production under this modern system, therefore, is made scientific, as well as the structures used in production. This scientific nature, not only of the factory but of the product of the factory, makes all work in it more or less intellectual, and this in itself is a civilizing element; but when it is understood that through the inventions that make up the factory system — and they are almost innumerable — people of very low attainments, accustomed to the crudest kind of work, are enabled to step up out of their low sur-

roundings on to a fairly intellectual plane and into associations which stimulate the mind, we see the benefits to mankind.

So many illustrations of this could be given that it seems only necessary at the present time to make the broad, general statement and pass to specific inventions not particularly belonging to the factory system as a whole; but if specific illustrations are deemed necessary we can point briefly to the question of the hours of labor, which, under the factory system, have been reduced from thirteen, fourteen, and fifteen to eight, nine, and ten a day. This has been the result of economic forces supported by law. While the working time has been greatly reduced, the remuneration for labor has been correspondingly increased, wages under the system being, at the lowest estimate, double what they were seventy-five years ago, and in most instances two or three times what they were under the hand system. These are the benefits to the workers themselves. Society has benefited through the greater productive power of the workers and the cheapening of the products of manufactures. Under the old hand system a common linen sheet cost the worker at least thirty-two days of hard labor. At the present time it can be secured as the result of but a few hours of labor. Such illustrations could be carried on indefinitely, but they all lead to the conclusion that the modern system brings mental friction and a contact of mind with mind which could not exist under the old system. It brings progress and intelligence; it establishes at the centers the public hall for the lyceum and the concert, and as an educational force its power cannot be contradicted. These statements are emphasized by the fact that prior to the factory system there had been no particular progress in the methods of production.

The Cotton Gin. The invention of the cotton gin stimulated the rapid expansion of the factory system, so far as it comprehends the production of textiles. Prior to the cotton gin the cotton wool, as

it used to be called, was separated from the seeds by hand, a slow, tedious process that rendered the product of the textile factories expensive, and crippled the volume of production, but with the cotton gin these difficulties were removed. It was an American invention, and it had a vast influence upon the welfare of mankind, because that welfare has been greatly enhanced by the power created to clothe the people. As one of its results, the exportation of cotton goods from England was made possible and the carrying of clothing to remote parts of the world successful. It has been said that the cotton gin gave a new lease to the slave system by making the labor of the slaves profitable, whereas under the hand methods it was not so profitable, and thus that the cotton gin had a dwarfing influence upon human welfare. Be this as it may, the general results of the effect of the cotton gin were in the interest of the human race, although locally it may have been detrimental to a particular class of people.

Illuminating Gas. Mankind is greatly indebted to the inventions which led to the practice of lighting cities and towns artificially. The invention of illuminating gas and the appliances by which it could be utilized must be considered as one of the greatest civilizers of the age. Prior to such practice cities were dark and furnished the very best opportunities for crime. With the lighting of cities crime decreased and the people were safer in their daily pursuits. While the lighting of cities can hardly be classed among machinery, nevertheless the discovery of the qualities of illuminating gas involved the construction of machinery by which it could be utilized, and it is one of the great inventions which have helped mankind in its upward struggle.

Steam and Electricity. While steam served to make the factory system possible and effective, it revolutionized the affairs of the world, and, taken in connection with the application of devices for making electricity serve the people, gave new impetus to knowledge

and brought all peoples into neighborly relations. Steam and electrical appliances must go together, because the generation of electricity for any large uses depends upon a motive power outside of itself, and steam is more generally used in the generation of electric current than water, although water is beginning to be used wherever the power can be applied with the most satisfactory results; but water power is not modern, while steam is. With steam and electricity and the rapid transmission of intelligence and transportation of products, the real face of industry and of commerce has been changed. Steam is applied as well to the loading of vessels as to the power which moves them when loaded. Prices of commodities are thus equalized. The telegraph announces the condition of the markets in all parts of the world, and steam responds in supplying the waste places. By the two great forces famines have been reduced and in great degree become entirely impossible, but when they do occur the impulses of the people are first moved by electricity to supply those suffering, and by steam the actual supplies are carried quickly where needed. Thus under steam and electricity the human race becomes a great brotherhood instead of a collection of segregated peoples, each caring for itself and little or nothing for the other. In the deepest philosophical sense, then, steam and electricity embody inventions in the modern world to which the human race owes an enormous debt, which it can pay only by appreciating the resulting benefits and conducting itself in accordance therewith.

Steam and Electrical Appliances. But the appliances which enable mankind to utilize steam and electricity constitute the true inventions, for the powers that lead to these inventions are natural. These appliances have raised the grade of labor everywhere. They have made possible great engineering enterprises which could not have been carried out without them. Electrical and steam engineering call for a higher grade of skill than could have been utilized in

any occupation under the old system. This means higher wages or salaries and a higher grade of men. Men, therefore, are constantly stepping from ordinary industrial walks of life into higher callings made possible by steam and electricity, thus adding practically and really to the demand for labor of all kinds, increasing thereby the general proportion of the population engaged in remunerative labor. The invention of the telephone, the expansion of the telegraph, and the various other appliances for the use of a great natural power are constantly adding to the opportunities in life for engaging in a high grade of employment.

Electric Street Car. Perhaps one of the most effective devices to which electricity has been applied is the trolley car. A consideration of the modern means of rapid transit in our great cities and between cities and the rural districts immediately surrounding them leads to the conclusion that, sociologically, no invention or application of inventions has been so potent during the last quarter of a century as the electric street car. The men who work for wages are enabled by it to remove from the congested districts of cities, where their working places are located, to the healthful surroundings of the country, and this very influence is tending to depopulate congested cities. Statistics show that in Philadelphia, New York, Boston, London, and no doubt in other cities could the facts be ascertained, there is a constant decrease in the number of people living in the congested districts of cities. Of course there is another influence helping this movement; that is, the necessity for erecting great business houses. This deprives the inhabitants of such districts of house room, and they are obliged to move into the suburbs. The trolley car helps them in this movement. On the other hand, the suburban population is given the privilege, at cheap rates, of working in the cities during the day and returning home at night.

Much is said about the concentration of population in cities.

The concentration is not in the cities proper, but in the suburban districts surrounding them. Here those who come from the country and find work in the city make their homes. Here those who are crowded out of the city also make their homes. These two forces meet, and are together constituting one of the grandest populations the world has seen. The influences in these movements, resulting directly from the invention of methods by which electricity can be applied, have a marked and decisive effect on human welfare. They save labor; they save exhaustion; they preserve physical strength, and in turn they help stimulate the mind and lead to a higher intellectual growth, for education is necessary not only to the comprehension of these things but to their practical application.

Elevators. A modern invention which has enabled the business man to accomplish more in a day and with less fatigue than of old is the elevator in business and public buildings. The elevator can hardly be considered as an individual invention, but it represents the application of well-known mechanical devices set in motion by steam, water, or electricity in such a way as to benefit the human being individually. The old-time stairway exists, but is not much used. The elevator takes one easily and rapidly to any height and without any fatigue. It has made the upper stories of business and public buildings just as desirable as the lower ones, and in fact far more desirable, for in the upper stories the professional or business man can spend his days with good light and air; hence, physically and in a hygienic sense, the elevator is a blessing for mankind.

Clothing. The application of invention to the manufacture of clothing, including boots and shoes, has resulted not only in securing better conditions of health but in making life itself easier and more congenial. A fairly well-dressed man or woman is certainly a better type than a shabbily dressed one, and under modern invention clothing can be procured cheaper than at any time during the last

century, and of a quality which surprises one when the price is considered. But the most effective and perhaps far-reaching influences from the manufacture of clothing are to be found in waterproof fabrics. Rubber is a natural product, but the application of it to the uses of man took inventive genius, and to apply it so that textiles could be made waterproof took still further invention. Waterproof clothing, therefore, is not only an invention of itself, but its manufacture required other inventions applicable alike to other classes of goods. The health and welfare of the people have been enhanced many fold by the use of waterproof clothing, and, indeed, one can hardly estimate the benefits of the inventions which led to its practical use. Life is safer, health is securer, longevity is enhanced by the use of modern waterproof goods.

Sewing Machine. The sewing machine may be considered as one of the important modern inventions which have had a decided influence upon human welfare. It has not only increased the working capacity of the people, but it has brought into existence a new line of occupations. The construction of the machines themselves, the great efforts necessary to put them on the market, and their special uses when brought into active employment, all lead to an expansion of industry and, hence, to an expansion in the number of employments open to men and women. They have supplemented to a great extent the inventions of shoe machinery, and enabled manufacturers to produce most excellent goods at a low price. They have made the sewing-girl's life more endurable, and have helped to cultivate a taste in clothing by the opportunities to use forms and devices in the make-up of dress goods that would not have been thought of under the old hand methods. There are, to be sure, evils in the use of the sewing machine, as in the use of all machines, but when judiciously used it must be considered as one of those inventions the loss of which could not be tolerated.

Typewriter. The modern typewriter has expanded human possibilities from four to six fold. A few months ago the writer listened to a statement by the president of one of our largest universities. The topic of the conversation turned upon human abilities and their limitations. He said that with the use of the typewriter he could accomplish from four to six times as much as he was formerly able to accomplish without it. Hence his usefulness was greater to mankind and his business abilities far superior to those of old. He said he did not see how by any possible invention he could increase his product of work, and the testimony he gave was the clearest on the subject that could be obtained. Take a business house, for instance. The vast correspondence necessary to the conduct of the great establishments of the present day could not be carried on without the use of the typewriting machine. A business man takes up his correspondence in the morning, dictates his replies, and after an hour or two is at liberty to attend to other affairs, giving his attention to the details of his house, whereas formerly it would have taken him quite if not all day to accomplish, so far as correspondence is concerned, what he easily accomplishes in an hour. So with official business the same is true, and the fact that the use of the typewriter has opened an occupation in life not known before offsets some of the displacements that take place when machines are first applied. The education necessary for an efficient typewriter operator has stimulated school work. One cannot become a successful and intelligent operator of the typewriting machine unless he understands more than the old hand copyist was expected to know. The typewriter operator must be well grounded in grammar and in all that belongs to it; he must understand the construction of sentences and the use of capitals and punctuation marks, and in general must be a well-read, well-educated man. As an occupation for women, typewriting offers a respectable and an intellectual class of work.

Anæsthetics. An invention which cannot possibly be called a machine, but which has had perhaps as great an influence on the human race as any invention that can be named, is that of anæsthetics. It has removed the horrors of surgical operations; it has saved life where under the same operation life would have been lost; it has enabled the skillful surgeon to do what he could not do without their application. Under the old way, when the patient was obliged with full consciousness to undergo an operation, the surgeon would often stop short of the minute investigations necessary to ascertain the real cause of existing difficulties, but with the patient safely unconscious the surgeon can carry his study and inquiry to as great an extent as may be found necessary. Often, after an intelligent diagnosis, when a surgeon begins to operate he finds complications which he did not foresee. The use of anæsthetics enables him to work until he removes all obstructions and to make a complete instead of an incomplete operation. Human life is therefore worth more on account of this invention or discovery. Diseased conditions yield where they would not have yielded; hence, while anæsthetics cannot be classed, as stated, with machines, they must be classed with inventions and with those that have had the very greatest influence on the welfare of the human race.

Agricultural Machinery. The application of machinery to agricultural pursuits has been slow and difficult but successful. The single, small farmer cannot afford to own and operate expensive machines. The farmer on a great scale reduces farming to a manufacture, almost, for he uses machinery in every direction. Under its use it is rarely necessary for him to touch a tool, and in the harvesting of some crops he need not touch the product from the time of the sowing of the seed till it is sent to market. He does not touch it in the sowing, nor in the cultivating, nor in harvesting or threshing, nor in transportation or milling. He may put his hand to it when he

comes to use it as a food. This result has induced the small farmer to engage in co-operative enterprises, by which a number of neighbors club together and purchase the necessary machines. The application of machinery to agriculture has not resulted in what was feared a few years ago, the bonanza farm. As a matter of fact, the average size of farms in the United States constantly decreases, but intensive farming increases. The land is made to produce more and in a cleaner way by the use of machinery.

It is wonderful how many ramifications there are to this use of machinery, and to enumerate all the different features of such use would lead us too far afield, just as it would to undertake to enumerate the machines necessary under the factory system. One concrete illustration may be given, however, which will clearly show the power of machinery in agriculture. It takes one hundred minutes to shell corn enough by hand to make one bushel of shelled corn, and one minute to shell the same quantity by steam shelling devices. Applying this to the crop of one of our large corn-raising states, which last year produced almost two hundred million bushels of corn, it is found that to have shelled this amount of corn by hand would have occupied each person in the state over ten years of age 9.5 days, while it would have taken the male population ten years of age and over nineteen days. The work was accomplished by machinery in fifty-six and four fifths minutes for each person of the population over ten years of age. Such illustrations, of course, could be calculated for various crops, but this one is sufficient.

It may be asked, What is the practical value of the use of agricultural machinery unless the price of the product is correspondingly decreased? The price is decreased, and food is cheaper on the whole as time goes on and as machinery is more generally applied; but the great benefit is that it enables this country to raise and market such immense quantities of wheat, corn, and all the great staple

products as not only to supply its own demands but to furnish other countries with food, and at a price fairly satisfactory to the toilers. Machinery has enabled the producer to sell crops at such a price as to warrant their exportation, and so the United States is the great food supplying nation of the world. The great industries of England and some other countries could not well be carried on without the necessary supplies from this country. This very power of the United States in respect to agricultural products is augmented by the use of machinery in the slaughtering of cattle and in the preparation and transportation of meat. Transportation has reduced the expense to such a degree that a whole year's supply of food can be brought from the West to the East at a very small cost; and while the East does not compete with the West in these respects, and cannot do so, it is allowed to devote its attention to the manufacture of other things, it being cheaper, far more so indeed, to secure its food supplies from other parts of the country. And now the use of machinery in mining coal is augmenting the transportation of agricultural supplies. It is furnishing not only the food to enable foreign countries to continue their industrial enterprises but the fuel with which to run their establishments. So machinery is vitalizing every productive force of the United States and enabling it to assume supremacy in its productive capacity, in its actual productions, and in its commerce.

Printing. One other illustration showing how human welfare is enhanced by the application of machinery must suffice at the present time, and that illustration is to be drawn from printing. As printing was the first great invention which influenced the world, so it is the latest in the same direction. The use of movable types required composition by hand, and the methods of composition met with no improvement, except through the form of the type and means for their adjustment and their use upon the presses, until within a very

few years, when the typesetting machines were perfected. Under the old method of composition a fairly expert compositor could set 1000 ems an hour, while with the use of the linotype machine he can set 4500 ems in the same time. This invention followed the perfected presses, which embody the very magic of inventive genius. One of the latest sextuple stereotype perfecting presses has an aggregate running capacity of 72,000 eight-page papers per hour. One pressman and four skilled laborers using one of these presses will print, cut at the top, fold, paste, and count (with a supplement inserted if desired) 72,000 eight-page papers in one hour. With the old hand press it would have taken a man and a boy one hundred days, working ten hours per day, to produce the same results. The power of the press, therefore, is enhanced many fold; it cannot be calculated. Its use is revolutionizing many affairs, and among them there is no greater revolution than that seen in the conduct of a political campaign. Printer's ink is rapidly taking the place of the stump orator. In 1896 there were sent out from party headquarters nearly two hundred million copies of documents. This feat could not have been accomplished without the use of the modern power press.

We need not discuss some of the evils of the modern press, for we can all gratefully acknowledge the fact that the balance of influence is on the side of good, and vastly so. Campaign committees understand perfectly well that the intelligence of the people is to be reached by comprehensive statements of fact. The orator may deal with many generalities and introduce many statements that cannot be supported by facts, but a printed document must be in the main true and unassailable. So leaflets and short pamphlets are sent out by the million to the farmers and the mechanics of the country, giving them the opportunity to sit down quietly by themselves and study the statements instead of listening to the oratory and generali-

ties of the stump speaker. The personality of the political speaker will always hold its place and have its force, but with a rapidly increasing population he cannot reach every one. The printing press can, and hence it is utilized in the most effective way by political parties.

Practical Results of Modern Printing Processes. The cheapening of books is the direct result of invention. It is a pretty poor specimen of humanity that cannot at the present time avail himself of some reading matter. He is surrounded by it on every hand; he finds it everywhere. The very best books are brought out in cheap editions, and one may read and study to any extent he may desire, and under our modern methods the desire generally exists. A farmer up in New England, in talking with a bright New York business man, said: "You men in New York are pretty smart and know a great deal, but let me tell you that you know it only a few hours before we do." This is true. The printing press drives the information from the great centers out into the country districts in every direction. This could not be done without the power presses that are used.

Effect of Machinery on Labor. The antagonism to the use of machinery in production is usually concentrated in the argument that by its use a decreasing number of persons is employed. This argument creates apprehension and often leads to bitter strife. An examination of all the facts bearing upon this point teaches, however, that the apprehension is not well grounded; that while machines on their introduction may and often do displace labor, the general result is to secure an increase in the number employed. The great number of new occupations that have been opened by the introduction of machinery, the vast works necessary for its construction, and the bringing in of a large body to distribute the products of machinery lead to the belief that the argument has no real foundation. Statis-

tics prove also that the proportion of the whole population employed in machine-using countries is constantly increasing and that the proportion of skilled to unskilled workers is constantly enlarged.

The illustrations given relate almost entirely to American inventions. Cotton machinery belongs to the English, steam is an international matter, and the other great inventions referred to are distinctively, if not wholly, American. Ether, while discovered in Europe, owes its practical application to American ingenuity, while the discovery of chloroform is strictly American. Variations of these inventions have been made by other nations, but the initiative genius in them has been American. The Americans constitute the most intense type of machine-using people, and hence illustrate more broadly than any other the benefits which machinery has brought to mankind.

As a summary, we may enumerate the wonders of American invention. They are the cotton gin, the adaptation of steam to methods of transportation, the application of electricity in business pursuits, agricultural machinery, the modern power printing press, the ocean cable, the sewing machine, waterproof goods, the typewriting machine, and anæsthetics. These may be called the great wonders of American invention.

POWER.

ITS PRODUCTION AND USE.

What Energy is — How a Steam Engine Works — Essential Parts of a Steam Engine — Practical Efficiency — Steam Engine Records — The Limit Nearly Reached — Evolution of the Steam Engine — Denis Papin — Thomas Newcomen — Watt and Boulton — Corliss Engines — Man's Debt to the Steam Engine — Evolution of the Locomotive — The Stephensons — Rainhill Contest — First Locomotives in America — Growth of Locomotives — Fastest Trains in the World — How Gas Engines Work — Advantages of Gas Engines — Compressed Air — Liquid Air — Fallacies and Uses — Mining Horrors — Safety Lamp — Ericsson's Sun Motor.

MAN has increased his productive powers by making certain animals his beasts of burden and allying with his puny strength certain powerful forces of nature. Windmills are of a very ancient origin, the power of falling water was early appreciated and applied, but the greatest stride was made when the expansive force of steam was recognized and led captive.

In order to clearly and easily understand the manner in which steam engines, gas engines, dynamos, compressed air and military explosives do their work, it will be advisable to briefly call attention to the manner in which certain forms of energy, as heat, are made to labor for the good of man.

What Energy is. Energy is a convenient expression for an ideal measure of certain forces or reactions in nature, such as light, motion, heat. The sun is the source of energy, which it gives off to

the earth in the form of heat. The sun's heat falling upon the earth's surface produces changes in temperature, causing atmospheric currents, which man has utilized to turn his windmills and propel his ships. The sun's rays falling upon bodies of water cause vapor to rise, which descends later as rain, and, gathering into rills, brooks, creeks, and rivers in obedience to the law of gravitation, returns to Mother Ocean. Seizing advantages of broken surface, man has thrown dams across these streams and utilized the falling water to turn his water wheels, to move machinery, to spin the threads of his clothing or to grind his grain for bread.

Correlation of Energy. In prehistoric times the heat of the sun falling upon the earth was absorbed by gigantic forests, later to be changed into coal, familiarly known as "bottled sunshine." This same coal, burned in a furnace, may change water into steam to move an engine, to turn a dynamo, to furnish power for an electric light for a city. It is evident from this that energy of one kind may be changed into another, and from this has been deduced the law of Correlation of Energy: "All kinds of energy are so related to one another, that energy of one kind may be changed into energy of another kind."

Conservation of Energy is another principle. "When one form of energy disappears, an exact equivalent of another form always takes its place, so that the sum total of energy is unchanged." On these two principles rest the foundations of physical science. Energy, no more than matter, can be annihilated.

For convenience, common measures or units of these forces have been adopted. The power of work of the steam engine is usually expressed in one of three such units. The force required to raise one pound one foot is known as a *foot-pound*. This has no reference to time, but is a measure of pure force. When work to be performed is measured the element of time enters in. The force re-

quired to raise 778 pounds avoirdupois one foot (778 foot-pounds) is sufficient to raise the temperature of one pound of water from 39° to 40° Fahrenheit. This amount of heat is called a *British thermal unit*, and the required force, its mechanical equivalent.

Horse-power. The steam engines of Watt were largely used in coal mines and took the place of many horses. As a matter of convenience it was desirable to have the power of an engine expressed in such terms that it could be compared with the work of a horse. The raising of 33,000 pounds one foot high in a minute was found to be about as much work as the best horse could do. This was taken as a unit of measure of work. From it we have the *horse-power*, or the force required to raise 33,000 pounds one foot in a minute, or for a *horse-power-hour* sixty times that of a horse-power, or the force required to raise 1,980,000 pounds one foot in one hour.

Carriers of Heat. In steam or other forms of heat engines, pressure is an effect, not a cause. It is produced by subjecting some vehicle to the action of heat. Hydrogen gas will absorb the most heat and water stands next. The abundance of water renders it a cheap and convenient carrier of heat, for the work steam does is all caused by the amount of heat it carries. Water is made up of molecules, each composed of two atoms of hydrogen and one atom of oxygen. The molecules are in active motion and so small that each has a range of motion greater than its own dimensions. Lord Kelvin estimated that if a drop of water were magnified to the size of the earth its molecules would be about the size of a pea. The size of an atom is inconceivable, for our molecules are composed of several atoms.

Heat Causes Motion. When heat is applied to water its molecules move so rapidly and bump against each other so hard that the water cannot hold together as a liquid and separates or expands into steam. As more heat is applied the molecules move farther and

faster until the expansive force of the steam confined becomes terrific. If these molecules move more rapidly as heat is applied to them, they also move more slowly as the heat is taken away from them.

Limit of Motion. There is a point at which all molecular motion stops. It has never yet been reached by experimenters, but it is known to be about 461 °, or, to be exact, 460.7 °, below the zero of the Fahrenheit scale. Life depends upon heat, and there is no heat at the absolute zero. At this point not only would all life be dead, but all matter would be dead.

Combustion. In ordinary practice heat is produced by combustion and, leaving out the curiosities of the chemist's laboratory, means the uniting of some substance with oxygen, their union producing heat. The substance with which the oxygen will unite is called a combustible. The substance containing the oxygen is called an oxidizer, or a supporter of combustion. In furnace combustion a combustible, like carbon or hydrogen, is supplied in the fuel, and the oxygen is supplied by the atmosphere, an abundant and cheap supporter of combustion. Of all combustibles hydrogen gives off the most heat. One pound of it, consumed at a high temperature, with oxygen in the proportion to form water (H_2O) will yield 62,032 thermal units, or more than four times as much as carbon. Hydrogen will not burn at a low temperature. Hydrogen is found in "marsh gas" (CH_4) and consumed in the "Bunsen burner" gives the characteristic intense heat with little light.

Carbon is the most common combustible. It constitutes about 50 per cent. of wood and from 40 per cent. to 95 per cent. of coal. It will burn at a lower temperature than hydrogen, and consumed with enough oxygen to form CO (carbonic oxide gas) will yield 4,452 thermal units per pound, or mixed with enough oxygen to form CO_2 (carbonic acid gas) will yield more than three times as

much heat, or 14,500 thermal units. We make practical application of this principle when we open the drafts of a stove and admit more oxygen from the atmosphere to the fire to make the latter give out more heat. A pound of carbon requires for perfect combustion 2.67 pounds of oxygen, which must be supplied by the atmosphere, and their union sets free 8.94 pounds of nitrogen with which the oxygen was mixed, for nitrogen is not combustible and serves only as a diluent. The necessity of good ventilation in a room where a fire, lamp, or gas jet is burning is obvious.

A pound of coal contains carbon, hydrogen, oxygen, sulphur, and earthy matters in varying proportions. A pound of the best coal has latent within it about 15,000 thermal units and should raise from 95° F. and evaporate 13½ pounds of water at atmospheric pressure.

How a Steam Engine Works. The steam engine is a machine that converts heat into work. Suitable fuel consumed in a furnace is used to heat water in a boiler. The water may be within tubes around which the fire passes (water tube boiler) or the fire may pass through tubes (tubular boiler) surrounded by water. A quantity of water converted into steam at the same pressure will occupy 1700 times its original bulk, and, if closely confined, possesses great expansive force. This force is limited only by the temperature of the fire and the strength of the boiler. The steam generated in the boiler is confined and carried through a pipe to a *steam-chest*, connecting by means of openings called *valves* with a *cylinder* containing a *piston*. (See Figure A.) The mechanism is so arranged that the valves open and close to admit or expel steam in perfect time with the stroke of the piston.

Working of a Slide Valve. The slide valve is the simplest form used in distributing the steam in a steam engine. It is often called the D-valve, because the moving part is the shape of the capi-

tal letter "D." This form of valve has been superseded by the various forms of balance and piston valves except in the smaller and less economical engines, but it is the simplest form to study and from it the action of steam can be most easily understood. The accompanying diagrams will make clear exactly what a steam engine does at each stroke. To avoid confusion only the principal movements will be given. Having mastered these the reader can follow out the action of any of the complicated varieties if he chooses to do so.

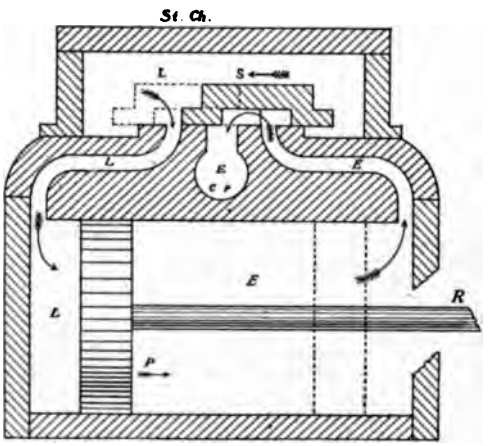


FIG. A. ESSENTIAL PARTS OF A STEAM ENGINE.

St. Ch. = Steam Chest; E. P. = Escape Port. R. = Piston Rod. L. = Live Steam, E. = Exhaust Steam, and the arrow its direction. P. = Piston Head, S. = Slide Valve, and the arrow its direction until it assumes the position shown by dotted lines.

Essential Parts. Figure A shows a cylinder into which steam is admitted under pressure from the boilers, a tight-fitting piston within the cylinder and slide valves which open and close the passages through which steam is admitted to or allowed to escape from the cylinder, and the piston rod which communicates motion to the crank.

Figures I., II., III., and IV. show in detail the action of the valve, the piston, and the steam.

Figure I. shows the relative position of the parts at the time when steam is most freely entering the cylinder. The position of the crank and its direction of rotation is shown by *h*. The position and direction of the piston is represented at *g*, while *f* shows the same facts as regards the valve. The valve moves back and forth across three openings (ports) in what is called the valve seat. By

the *steam ports*, *a* and *b*, the steam may enter and leave the cylinder, and *c* is the *exhaust port*, which communicates either with the open air or with the condenser. With the valve in the position shown in Fig. I. the live steam (steam at the boiler pressure) enters the steam port *a*, travels in the course shown by the arrows and enters the interior of the cylinder at *d*. Here it exerts its force upon the piston and drives it in the direction shown by the arrow. The interior of the cylinder represented as *e* is full of steam from the last stroke, and to permit the piston to move in that end of the cylinder this steam must escape. This it does by leaving the cylinder through the port *b*, passing through a hollow in the bottom of the valve to the exhaust port *c*. If the valve were to be fixed in this position, the steam would continue to enter the cylinder at full boiler pressure and drive the piston to the end *d* of the cylinder. The piston would in turn drive all the steam out of *e* and when the piston had reached the end of the cylinder, it would come to rest and stay at rest. But the valve is moving in the direction shown by the arrow, and it soon reaches the position shown by Figure II., when the next event in the stroke occurs. The live steam port has been closed by the face of the valve completely covering it, and pressure shut off from the boiler, but the

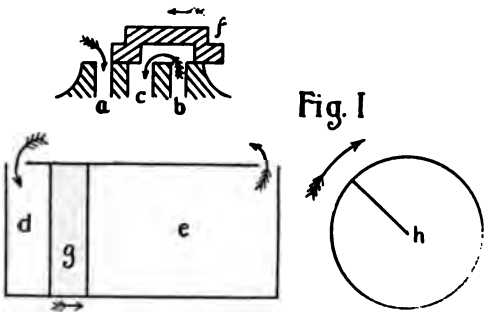


Fig. I

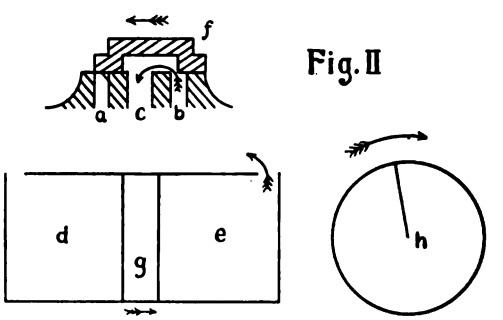


Fig. II

exhaust port is still in communication with the cylinder end *e*. The steam yet imprisoned in *d*, finding that it can expand by pushing the piston ahead, continues to do so. The point at which this expansion begins can be varied and the amount of live steam used regulated to do exactly the amount of work required. This is the part of the stroke to which more thought has been given than any other, for upon the accurate adjustment of the ratio of expansion depends the economy of the engine more than on any other one feature of the stroke. As the piston nears the end *e*, it must be slowed down and stopped in such a manner as to reduce to the least possible amount the jar to the engine. This is done by adjusting the valve to reach the position shown in Figure III., when compression begins. Expansion is still going on, for the valve has not yet uncovered the port *a*, and at this point the valve also covers the port *b*, thus imprisoning the small amount of steam still remaining in *e*, and the oncoming piston compresses it. As it is compressed it exerts a cushion-like action on the piston and gradually stops it.

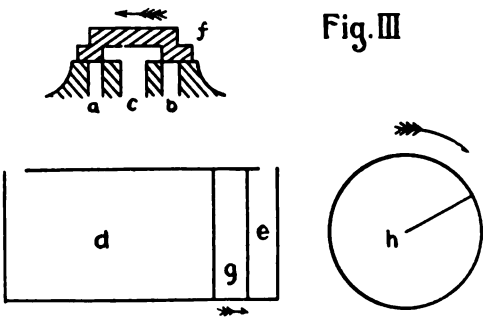


Fig. III

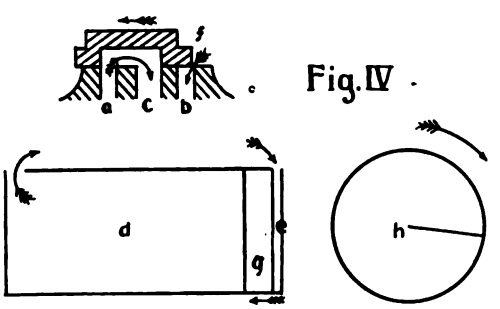


Fig. IV

How the Piston is Stopped. The point at which compression begins is so placed that the steam in *e* will at the end of the stroke have been compressed by the force of the steam in *d* and the momentum of the moving parts, until its pressure is very little less than

that of live steam. This does three things. It stops the piston so it can be started in the other direction; it allows the incoming steam for the next stroke to meet steam at nearly the same pressure and thus keeps the engine from jumping and jerking; and it heats the end of the cylinder to the temperature of the incoming steam and so reduces condensation. Then the event shown in Figure IV. takes place. The valve moves a short distance further and allows live steam to enter port *b* and pass to cylinder end *e*, and at the same time throws open the passage from port *a* to the exhaust port *c*.

The Return Stroke. The piston finds that the steam which has just driven it into the end of the cylinder is hurrying away through the exhaust port, while on the other side of it there is a new supply of steam coming in and insisting upon its retracing its course. This it does, and passes through exactly the same course of events in the backward journey. The valve is so planned that it works both ways, and it always turns and starts back just after it has seen the piston safely started upon its new stroke. So the motion continues, the piston always hurrying to get away from the steam and the valve always confronting it with a new supply of steam just when it begins to think it has found a corner where it may stop to rest. To the piston head is attached the piston rod (*R* in Figure A). This passes through one end of the cylinder, the opening being made steam tight, and is supported at the end by guides which hold it steady in its to-and-fro motion. To the end of the piston rod that plays between the guides is fastened a movable arm, the other end of the arm being attached to a crank used to turn the machinery. This movable arm is the *connecting rod* that conveys the to-and-fro motion of the piston rod to the crank which converts it into circular motion for the use of machinery.

Limitations of the Steam Engine.

The engine is a machine which takes the steam brought to it, converts a portion of the heat it contains into useful work, and

throws the rest away. We have seen that water (H_2O) contains molecular energy ranging from the point at which all life ceases, or the absolute zero, 461° below the zero of the Fahrenheit scale, up to any point to which it can be heated. The engine is wasteful, for it uses the steam through only a portion of this range of temperature.

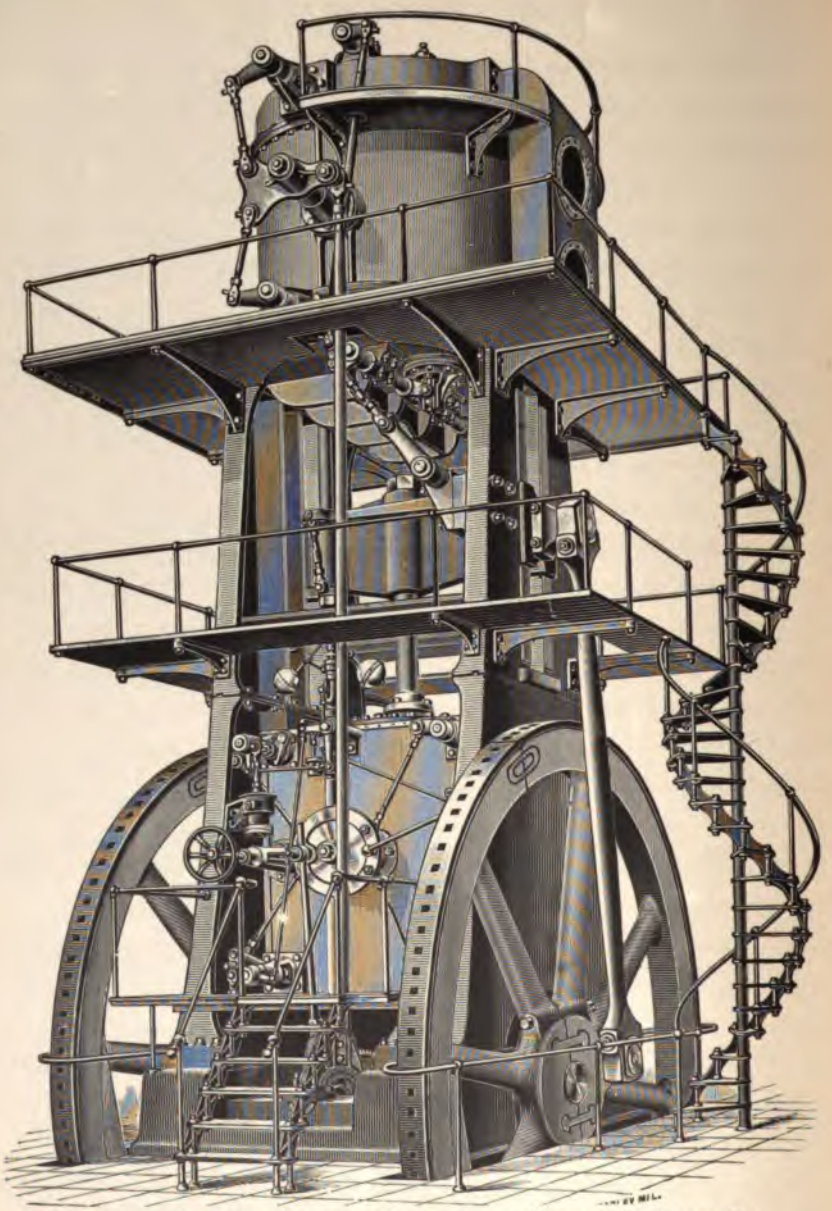
Theoretical Efficiency. The efficiency of the engine is expressed by the formula: $T' - T^2 \div T' + 461° =$ Efficiency. This is not as difficult as it looks. T' means the temperature of the steam when admitted to the cylinder; T^2 the temperature of the steam when expelled from the cylinder; $T' + 461°$, the temperature of the steam above absolute zero, and this is found by adding to the temperature of the steam above the Fahrenheit zero the 461° necessary to bring it down to absolute zero. Using this formula: suppose the steam to be admitted to the cylinder at a temperature of 370° F. Suppose the steam to be expelled from the cylinder at a temperature of 140° F. The engine has then used it through a range of 230°. When the steam was admitted to the cylinder it was 370° F. + 461° = 831° above absolute zero. The steam then had 831° of heat. The 230° used by the engine divided by 831° equals .277, the engine's efficiency; in other words, the engine used a little more than one fourth of the heat and threw the rest away as a waste product.

Practical Efficiency. It is plain that the wider the range of temperature through which the steam is used, other things being equal, the higher the efficiency of the engine. The foregoing is the performance of an ideal engine, but there are wastes attendant on its practical use, and the engineer gets out of the steam furnished him only about 60 per cent. or 85 per cent. of the ideal, or from 15 per cent. to 21 per cent. of all the heat the steam contained. Let us consider the losses. The very manner in which the coal is consumed in the furnace necessitates, under the best conditions, considerable

loss due to imperfect combustion, escape of heat up the chimney to maintain draft, radiation from contact of hot surfaces with the atmosphere. In good practice this would leave about .6 of the original heat to be used for the generation of steam.

Engine Waste. Engine wastes are due to *radiation*, *conduction*, and *initial condensation*. The first is the loss of heat radiated from the cylinder, steam pipes, etc. The second loss is due to the conduction of heat from the cylinder to the engine frame and engine bed. The chief loss is the condensation within the cylinder itself. When the steam valve opens, the hot steam from the boiler rushes in and is brought in contact with surfaces which have just been exposed to a lower temperature, hence are cooler than the incoming steam. These surfaces absorb part of the heat from the steam entering and the heat so absorbed cannot be used to perform work.

Condensation. Reference to Figure 1 shows hot steam is entering at the end *d* and escaping at end *e* into the open air, or a condenser, at a much lower temperature. End *c* continues to grow cooler and when, as in Figure 4, hot steam is admitted into it it is so cool that it takes a portion of the heat from the entering steam. The end *d*, Figure 4, is now discharging its steam into the atmosphere or condenser and parting with some of the heat in its walls to the escaping steam. The piston rods and valve rods, moving in and out, are alternately heated and cooled. These rob the steam of part of its heat. If the surface of the metal brought in contact with steam is cooled enough to deposit a thin film of moisture it renders the escape of heat from steam to metal easier, hence the gain in efficiency by keeping the steam and the cylinder as hot as possible. The loss due to cylinder condensation is often 50 per cent., rarely less than 25 per cent. Friction can never be wholly done away with so long as the force of gravitation exists, so here is another loss ranging from 3 per cent. to 20 per cent.



VERTICAL BLOWING ENGINE. MADE BY THE EDWARD P. ALLIS CO.

This is the type of engine used to furnish the blast for smelting ores.

How a Condenser Saves. Atmospheric pressure is 14.7 pounds to the square inch. When an engine expels its steam into the open air the piston head has to work against this atmospheric pressure. The economy of engines can be improved in several ways. An exhaust pipe may carry exhaust steam from the cylinder to a chamber called a *condenser* and bring it in contact with a spray of cold water, which suddenly condenses it. The condensed steam is then pumped out by an air pump and returned to the boilers. About three pounds pressure is required to run the condenser, and the difference between the condenser pressure and that of the atmosphere is the saving to the engine. Further economies will be discussed under the subject of compound engines.

Improvement of the Engine. The best engines of Watt produced a horse-power-hour on 63½ pounds of water and 10 pounds of coal. The next generation brought it down to 40 pounds of water and 5 pounds of coal. Later the Sickles cut-off and the Corliss engine reduced it to 30 pounds of water and 3 pounds of coal. In 1890, 15 pounds of water and 1½ pounds of coal were required. Engines of steamships are not the most economical, yet those of the *Deutschland* have produced a horse-power-hour for each 1½ pounds of coal consumed. No great gains in bulk of coal consumed or steam used can now be made. Any radical improvement in the amount of work gotten out of heat energy must come from some other method of using heat. "All the expenditures of heat in the engine are now recognized, their magnitudes have been measured, the loss governing their variation with the usual conditions have been in some cases closely, in other instances roughly, determined." *

"As the steam engine now is, we are rapidly approaching the limit of the possible in regard to its efficiency, and naturally further

* A Manual of the Steam Engine — R. H. THURSTON.

progress will be at a slower and slower rate. The greater progress here will result from the studious effort to bring the average up to the present exceptional practice. In rare cases we have records of one I. H. P. per pound of coal per hour. This is already attainable, therefore, and the problem immediately before us is to make such records the rule rather than the exception." *

Best Records of Engines. The scientist and the builder co-operating have produced some wonderful machines. The engines of the Edison power plant in Duane street, New York, are said to have produced a horse-power-hour on a pound of coal. An Allis engine at Chestnut Hill station of the Boston Waterworks has produced a horse-power-hour on 1.062 pounds of Loyalhanna coal. The editor of the *Engineering News* states that these figures can be reduced to one pound per horse-power-hour simply by substituting Virginia Pocahontas coal, and suggests other changes by which he declares it might be reduced to 9-10 pound per horse-power-hour. †

The Limit Nearly Reached. When we recall that the early Corliss engine required three pounds of coal for a horse-power-hour we see how little room there is for improvement. Under the article "Coal" will be found a statement showing man's obligation to the machines that have enfranchised him. So great has been the development that one man with a machine is now able to produce as much as one hundred and twenty men one hundred years ago. The commerce of the world has, within a century, increased more than 1200 per cent., while its population has only rather more than doubled. The steam engine has made possible to every man within the bounds of civilization more of the world's material wealth in return for his labor.

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* *Marine Engineering*, September, 1900.

† *Engineering News*, September 27, 1900.

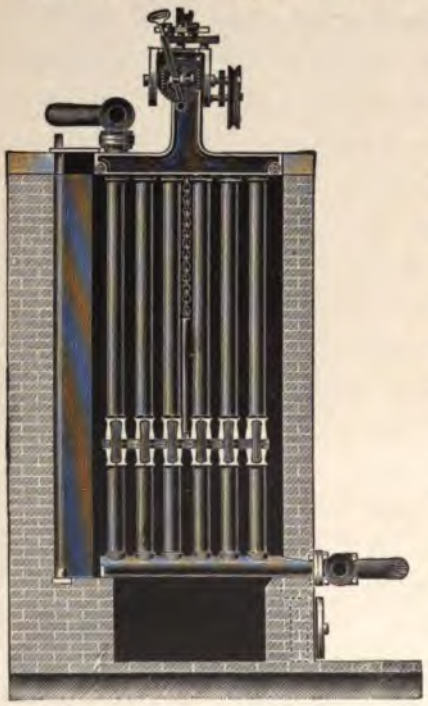
Compound Stationary Engine.

In a single cylinder engine the power is not exerted continuously, for the piston moves forward, stops, and retraces its path. This jar or vibration was rendered very noticeable when such engines were first used in connection with electric lighting, the vibration causing variation in the intensity of the light. To get rid of this vibration, but more for the purpose of reducing the loss of power due to condensation in the cylinder, the compound engine was introduced. By this term is meant using the steam in one cylinder, passing it to another, and using it again.

Meaning of Triple Expansion. The terms triple and quadruple expansion engines mean that the steam is used three or four times consecutively and has no reference to the number of cylinders, for a triple expansion engine may have more than three cylinders and a quadruple expansion engine may have more than four. If it were not for the loss due to cylinder condensation there would be little to be gained by using the steam in several cylinders, but this loss in a single cylinder engine frequently amounts to one half, and so leaves a great margin for improvement. It may be stated broadly that the loss in the different types of engines where the cylinders are not protected by jackets, etc., is about as follows: In the simple engine 50 per cent., in the compound engine 25 per cent., in the triple expansion 20 per cent., and the quadruple expansion 15 per cent. This waste can be reduced markedly by a good system of jacketing.

How Multiple Expansion Saves. Within the cylinder only a small "skin" on the inside undergoes alternate heating and cooling, for the rapidity of the piston stroke does not give time for more, and the heated mass of metal tends to keep up an average. By making the range of temperature within the cylinder small, condensation can be partly avoided and this is done by dividing the expansion of the steam into two, three, or four parts, so making the variation in tem-

perature in each cylinder only one half, one third, or one fourth as great as it would be in a single cylinder. The steam from the boiler enters the smallest cylinder of the set, is exhausted into a larger one, from there into another yet larger. So much room may be necessary for the third expansion that it cannot economically be contained in one cylinder and so may be divided between two. This is why a triple expansion engine may have three or more cylinders, or a quadruple have five, six, or seven.

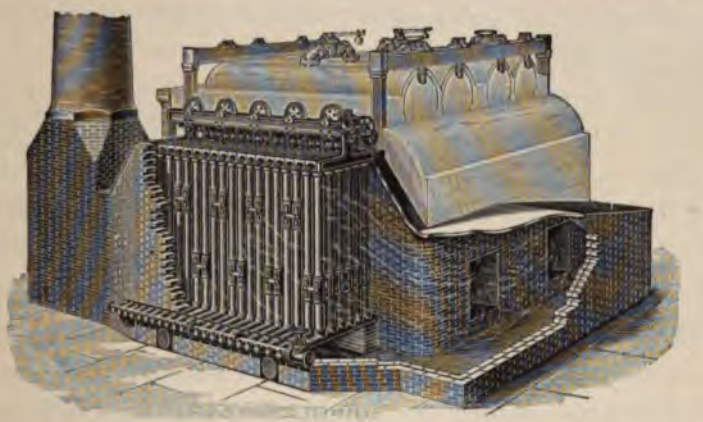


GREEN'S FUEL ECONOMIZER.

As the smoke and gases pass over the tubes of the Green Economizer they deposit soot on them and thus render them less efficient. This cut shows the device which automatically cleans the tubes and keeps them working at their maximum efficiency.

Green's Fuel Economizer. In general practice simple compound engines are worked at about 100 pounds boiler pressure; triple expansion, 125 to 180; quadruple, 200 to 250. So much attention is not being paid to the condenser as formerly, for better methods in boiler making and the use of steel in place of iron have produced boilers that will stand more pressure with safety, and have made it just as cheap and easy to add a few extra pounds to the boiler pressure as to take away as many pounds pressure at the condenser. Modern methods use the hot gases from the chimney and the exhaust steam to heat the water going into the boiler from which steam is to be made and save part of what was formerly wasted. If cold water is pumped into the boiler to be made into steam, a good deal of work must be done on

it to raise it to the boiling point. If the water is first heated by the exhaust steam and the gases escaping from the chimney, it enters the boiler carrying some of the heat that would otherwise be thrown away and so does not need so much work to bring it to the point where it will generate steam. Green's Fuel Economizer is a clever piece of mechanism designed for this purpose. It consists of a series



THE GREEN FUEL ECONOMIZER.

This cut shows how the Economizer is placed between the furnace and the chimney, using the heat in the gases that would otherwise be wasted, and heating the feed water up to such a point that all the boiler has to do is to turn it into steam at the same temperature. It is a clear saving of all the heat that was formerly wasted, and the turning of it to a useful purpose.

of tubes arranged vertically in the flue through which the gases from the furnace of the boiler escape to the chimney. The feed water is pumped through the Economizer into the boiler and on its passage heated by the escaping gas. Where these gases have a high temperature, from 450° to 560 , considerable heat that would otherwise be wasted can be utilized. The following claims are urged for the Economizer: —

1. The saving of fuel varies from 10 per cent. to 20 per cent. according to conditions.

2. The feed water is economically heated to a temperature above that attained by any other means.

3. It holds a great volume of water in reserve heated to the point of evaporation and ready to be delivered immediately to the boilers. This is an advantage in plants which run with loads subject to sudden variations.

4. It utilizes the heat from the escaping gases which would otherwise go to waste.

5. It avoids bringing cold water in sudden contact with the heated boiler flues and so prolongs the life of the boiler.

6. The slow current in the Economizer allows the sediment in the water to be deposited before it reaches the boiler. Sediment in boiler flues hinders the passage of heat from the furnace to the water within the flue. The sediment can be more easily "blown out" of the Economizer than out of the boiler flues.

Mr. Edward Green brought out the Economizer in 1845.

Superheated Steam. No matter how much heat is applied to water containing ice, the temperature of the whole mass cannot be raised above the melting point until all the ice is melted, so, steam heated in the presence of water cannot be raised above a certain temperature, for all the heat applied is taken up by the water and simply converted into more steam. There are two kinds of steam, the wet steam made in the presence of water, and dry steam which has been removed from the water and raised to a higher temperature. It is then known as superheated steam. The temperature to which it may be raised is limited only by the ability of the furnaces and the strength of the vessels containing it. But superheated steam is sometimes treacherous and violently explosive. It seems to be true that a thin film of moisture on the interior of pipes and cylinders renders the exchange of heat between the metal and the steam much easier and decreases the efficiency of the engine. Steam is superheated so that when brought in contact with the surfaces of the pipes and cylinders it will not be cooled down to the point of con-

densation. It may be said in general that in large plants the process of superheating steam is economical for it helps prevent, as we have seen, loss by condensation and makes the steam available through a wider range of temperature. However, superheated steam increases the corrosion of the piston and cylinder.

The averages of the efficiencies of several typical plants are about as follows. These engines were all worked with condensers:—

	Pounds per horse-power.	
	Steam.	Fuel.
Simple single cylinder,	25	2.8
Compound,	18	2
Triple expansion,	14	1.5
Quadruple expansion,	12	1.25

Where fuel is cheap the simpler forms of engines may be the more economical. The same statement holds good in those plants which run only a small part of the time. But with coal at $5.00 a ton, some form of compound engine gives the best service. At sea, where every pound of coal displaces a pound of paying freight and every ton a passenger, where coal must be used to transport coal, where a lighter and smaller boiler plant is a decided advantage, the multiple cylinder is evidently the best.

The Evolution of the Steam Engine.

Alexandria, a city at the mouth of the Nile, founded 332 B. C. by Alexander the Great, after whom it was named, was destined to become for centuries a famous seat of learning. Here flourished Hero, a Greek philosopher and mechanician (born 285, died 222 B. C.), who seems to have brought out the prototype of the steam engine which has revolutionized the industrial forces of the world. Hero's engine, Æolipyle, was a hollow metallic sphere supported between two trunnions through which steam from the boiler passed to the interior of the sphere. At right angles to the trunnions two

bent arms issued from the sphere and through these the steam was discharged into the atmosphere, which, reacting upon it, caused the sphere to revolve. Something similar is seen in the revolving lawn sprinklers of to-day. Hero was an able writer, and in his "Spiritalia sue Pneumatica" has described for us many clever mechanical devices used in the temples of the Egyptian gods to inspire awe and incite belief among their credulous worshipers. His work is interesting because it shows that some knowledge of the expansive force of steam had even then been possessed for a long time.

HERO'S ENGINE, 250 B.C.

Another steam or vapor engine of no little interest is the Vocal Memnon. This is well described by a famous Egyptologist. "When the secrets of a waning faith were revealed by the votaries of a rival belief, the celestial harmony was then said to be produced by vapor, rising from water concealed in a cavity in the statue, being made to pass through a tube having a small orifice fashioned in a manner similar to that of an organ. As long as the fluid was heated by the rays of the sun, mysterious sounds were heard by the assembled worshipers, which died gradually away, as the solar influence was withdrawn from the gigantic idol." It was not until the gloom of the Dark Ages had lifted that any practical progress was made in the application of steam as a motive power.

Baptista Porta, in 1606, described and illustrated a plan for the first steam pumping engine. It consisted of a furnace, a boiler, and a box partly full of water. A pipe from the boiler connected with the box above the water line. Another pipe with one end beneath the water leads out of the box. The box, being filled with water, was tightly closed and a fire built under the boiler, the steam from

which passed to the box. As the steam pressure bore down upon the water the latter was forced out through the delivery pipe to a height varying with the boiler pressure. When the box had been emptied, steam was shut off, the box refilled, and the operation repeated. The plan was too cumbersome to be economical, but it was the forerunner of Savery's engine. In 1615 De Caus improved upon Porta's engine by doing away with the water box, and connecting the pipe directly with the boiler. By this means he delivered hot water at the point desired, thus achieving his object. The "creative imagination" of many countries was soon working upon the problem, but it was in England that the greatest strides were made, and that country may be justly called the birthplace of the effective steam engine.

It is amusing to note that the story of "Watt and his teakettle" is anticipated one hundred years in the career of the Marquis of Worcester. A partisan of Charles II., he was captured and imprisoned by the Cromwell party in the Tower of London. While cooking his dinner in an iron pot he is said to have watched the rise and fall of the iron lid as the steam gathered and escaped. After the Restoration he actually completed a rude machine capable of raising a column of water 40 feet.

Origin of the Safety Valve and Piston. Denis Papin (see Steamboat) for a time resided in England, where he perfected his "Digester," a process of extracting the gelatin from bones by dissolving them in steam at a high pressure. Warned by an explosion or two, he devised the safety valve. This was a tapering opening into a boiler and made steam-tight by fitting into it a conical plug. The plug was held in place by weights so graduated that when the pressure within the boiler had nearly reached the limit of safety it would raise the plug and allow the steam to escape. This with some refinements of mechanism is the safety valve of to-day. Papin is credited with the first application of the piston to the steam engine.

He designed a long upright cylinder fitted with a piston rod passing out through the top. A small amount of water was admitted to the cylinder and a fire built underneath the bottom. The steam, expanding, forced the piston to the top together with any weight that might be attached to it. To return it to its original position the fire was withdrawn from beneath the cylinder, and as it cooled the steam within condensed and the atmospheric pressure forced the piston back to its original position. Crude, slow, and unserviceable as was Papin's device it was the ancestor of the piston that in our modern high power engines moves with almost lightning-like rapidity. Strange as it may seem, the piston was a disappointment to Papin and he desisted when on the very threshold of a great discovery.

First Use of Steam Engine. The drainage of mines was a serious problem in England, and the first practical working steam engine was applied to this purpose. To "Thomas Savery, Gentleman," a Cornish mine-captain, was issued in 1698 a patent "for raising water and occasioning motion to all sorts of mill work by the impellent force of fire." In 1699 he exhibited his model before the Royal Society, where it was favorably received.

His pumping engine was placed near the bottom of the mine to be drained, and a fire built under the boiler, from which steam was conveyed to a long oval-shaped copper cylinder. The bottom of the cylinder connected with two pipes, one a suction pipe that led to the water below, the other a discharge pipe through which the water was forced out of the mine. Steam from the boiler was admitted to the cylinder and the valves closed. The cylinder was next sprayed with cold water. The steam within condensed, a vacuum was formed, and the water from the mine rushed through the suction pipe into the cylinder. The valve in the suction pipe was then closed and the one between the cylinder and the boiler opened, steam from the boiler entered the cylinder and forced the water out

of the cylinder through the delivery pipe. Savery constructed his pumping engine in duplicate and had a small boiler in which he heated the water supplied to the large one, thus reducing "condensation" in the large boiler. If heat is applied to a boiler after all the water within it has been turned into steam, the steam becomes superheated and explosive. That he might know how much steam and water he had within his boiler Savery fitted to it two stopcocks; one above the desired water level, the other below. If on opening the upper one water came out, that indicated too much water in the boiler, and the supply to the boiler was shut off. If on opening the lower one steam came out, that showed that the water was too low, and a fresh supply was admitted. These, with some improvements, constitute the gauge cocks now used.

Savery's engine used what was a comparatively high pressure for the rude boilers of that time and explosions were not unknown. Although Papin had invented the safety valve several years before, it was not until after Savery's death that it was applied to steam engines. The Savery engine was necessarily wasteful, for the steam from the boiler was partly condensed when brought in direct communication with the cold water in the cylinder. The vacuum created would lift the water only about 20 or 22 feet and the engine complete under the best circumstances had an effective pumping range of about 90 feet. To get the water out of a deep mine a series of engines, one above another, were built at different levels, each requiring some one to operate it.

Newcomen's Engine. Thomas Newcomen (1650?–1729) of Devonshire, England, was the maker of the first real steam engine. With the exception of Papin's experiment, the engines of Savery, the Marquis of Worcester, etc., were but modifications of Hero's engine Æolipyle. One vessel in the earliest engines served as boiler, engine, pump, and condenser, and did none of its duties well. New-

comen improved upon Papin's piston. He constructed a large upright cylinder, fitted it with a piston, passed the piston rod out through a cover in the top, and attached it to one end of a balance beam (walking beam), the other end of which operated a pump down in the mine. The pump being heavier than the piston, drew the latter to the top of the cylinder. When the piston was at the highest point, steam was admitted into the cylinder at the bottom, then all the valves were closed and the cylinder sprayed with cold water. This reduced its temperature and condensed the steam inside it, forming a vacuum within. Twelve cubic feet of the atmosphere weigh one pound. Its pressure on each square inch of surface averages 14.7 pounds. When the vacuum was created in Newcomen's cylinder the atmospheric pressure forced the piston to the bottom of the cylinder. This raised the other end of the walking beam and operated the pump. When the valve leading to the boiler was opened the vacuum was destroyed and the piston rose to the upper part of the cylinder. The operation was then repeated. To make his piston air-tight Newcomen covered the top of it with water.

Improvement from an Accident. The next marked improvements were due to an accident and a lazy boy. One day, greatly to Newcomen's surprise, his steam engine made several rapid strokes in quick succession without any reference to the action of the valves. On taking his machine apart to find out the difficulty, he saw that a little water had trickled through from the top and being brought in contact with the steam condensed it instantly. He was quick to perceive the significance, and instead of applying water to the outside of his cylinder turned a tiny jet inside and increased markedly the efficiency of his engine. It was now able to make six or eight strokes a minute but required an attendant who must open and close at the right moment the valves controlling the steam and the condensing jet.

Boys were employed for the work. One of them, Humphrey Potter, liked to play marbles and found the task of opening and closing those valves six or eight times a minute a most irksome one. Setting his wits and his eyes at work he observed that the valves were opened or closed every time the walking beam was in a certain position. He devised a system of strings and bits of wood which he stealthily attached to the engine. When watched he would open, and close the valves by hand. When left alone he would apply his "scroggan" and play truant. One day calamity in the person of Newcomen overtook him, but the engineer was quick to perceive the significance of the boy's crude snarl of string, for when worked out by the hand of the master it made the engine fully automatic and raised the speed of its stroke from six or eight per minute to fifteen or sixteen. Newcomen was an able engineer, not only fertile in invention but quick to see and appreciate the efforts of others, and could perfect and apply to his own machine ideas that in other hands were crude and inefficient. His engine with minor improvements prevailed until the time of Watt. "The modern condensing pumping engine, however, is a Newcomen engine rather than a Watt engine, and Newcomen rather than Watt is the inventor of the steam engine."*

James Watt was born at Greenock, Scotland, January 19, 1736, and died August 25, 1819. The story of his experiments of the tea-kettle illustrates well the myths that attach themselves to the memory of all great men. As a boy he was of delicate constitution. He went to London when eighteen and apprenticed himself to an instrument-maker. When twenty-one, he went to Glasgow to enter business for himself, but trouble at once arose over trade regulations, for he was not a freeman or burgess of the town, and this threatened to put a stop to his business. Within the college walls such trade

*R. H. THURSTON.

regulations were not operative and the college authorities gave him a small room where he took up the trade of instrument maker to the college. He was of a philosophical turn of mind and his skill soon made him a favorite with the instructors of the college, and rendered the mechanical knowledge of the age accessible to him. There is evidence to show that he early began experiments with Papin's crude engine. Papin was a man eminent in the scientific circle of his age. Honorary titles had been conferred upon him by English educational institutions. In his experimental boat on the River Fulda he is said to have employed two cylinders with different timed strokes, so as to give a continuous exertion of power. Papin's descriptions of his experiments were published and preserved in the libraries of all the great institutions of learning. There is no reason why Watt may not have known of them. We are told that as early as 1760 Watt had improved upon Papin's cylinder by adding a valve to the bottom of it through which the steam might escape after the piston had been raised to its highest point and thus do away with the necessity of a vacuum.

JAMES WATT.

Watt's Important Discovery. A model of a Newcomen engine, placed in Watt's hands for repair in 1763, interested him still further in the subject. After repairing it he made experiments with it and remarked his surprise at the great amount of steam required to operate it. He conducted a long series of experiments until, meditating upon some means of reducing the waste, the idea of a separate

condenser is said to have burst upon him suddenly one Sunday. He placed near the cylinder a large chamber in which was a jet of water and turned the steam from the cylinder into it. The condensation produced a vacuum in the chamber, and the steam at each stroke rushed into the chamber, only to be condensed by the jet, and thus furnish the necessary vacuum for the next stroke. The water was removed by a pump driven by the walking beam of the engine. This, the first of Watt's brilliant series of inventions, made a useful machine from what had been of only doubtful economic value before. Still he was using the steam only to produce a vacuum and the piston was exposed at the top that the air might force it down. To keep his cylinder from cooling he put a jacket upon it. That the upper side of the piston might not radiate its heat too freely, he closed that end of the cylinder and passed the piston rod out through an opening. This naturally suggested the next step. If the steam could force the piston up, why could it not force it down? He packed the piston rod with hemp, wax, oil, and grease, admitted the steam to top and bottom of the piston alternately, and the first independent steam engine was born. It is well that he retained the condenser, for with the imperfect boilers then in use had an engine worked entirely above atmospheric pressure, the mortality attendant upon the operation would have put a serious damper on its general use.

Rapid Development of the Engine. Watt began a large model but, meeting with an accident and having but limited means, he was forced to give it up. He outgrew his trade of instrument maker and became a surveyor and consulting engineer. This brought him the acquaintance of Dr. Roebuck, a famous chemist and man of wealth, who advanced money sufficient to secure a patent and received therefor a two thirds interest. Financial trouble overtaking Dr. Roebuck, his interest in Watt's patent was sold to Matthew Boulton,

an inventor remarkable for his energy and enterprise as a manufacturer. Watt could not have had a better partner. After the inventors had spent a fortune on their engine they were able to offer it to the public in these words: "All that we ask from those who choose to have our engines is the value of one third part of the coals which are saved by using our improved machines instead of the old. With our engine it will not, in fact, cost you but a trifle more than half the money you now pay to do the same work, even with one third part included; besides an immense saving of room, water, and expense of repairs." With the adoption of their engine fortune poured in upon them.

Invention of the Crank and Valve Gear. Watt and Boulton now brought out in succession various improvements such as the "governor," which regulates the supply of steam to the engine according to its needs. In all other engines steam had been applied from the boiler during the whole stroke of the piston. The jar resulting at the end of the stroke was a difficult problem to overcome. Watt cut off the steam before his piston had completed its stroke, and as it slowed down admitted steam on the other side of the piston to form a cushion. Although he had stumbled upon the discovery of the expansive force of steam, he died in ignorance of it. He invented the indicator, an instrument that gives a tracing showing the exact pressure within the cylinder at every point of the stroke. This suggested other improvements. The engine was as yet a pumping machine having only the up-and-down motion of piston and walking beam. Watt's friends claim that he gave a plan for a pattern of a crank and connecting rod to a workman named Cartwright to make for him. Cartwright is said to have sold it to a man named John Steed, who secured a patent in 1779. It is significant that the steam engine, which we seem to think has existed for ages, was so crude one hundred and twenty years ago that it could not

convert its power into circular motion for the use of machinery. He was not successful in his suits with Steed over the application of the crank and was forced to substitute a small cogwheel engaging a larger one to secure circular motion. However, the engine was made available for all machinery. Hornblower brought forth a compound engine in 1790 but Watt sued him for infringement and won his case. The steam engine as it left the hands of Watt was essentially complete, and the era of fundamental invention had closed.

Corliss's Improvement. Various improvements in valve gear were made or foreshadowed until Corliss in 1849 produced an engine of new design and construction in which were embodied the best ideas of the previous half century. The Corliss engine is to-day the best type of the single cylinder slow-acting engine. Corliss left the engine complete in all its essential characteristics. Since his time progress has consisted in the refinement of the mechanism, the improvement of the materials, and the adaptation of the engine to the duty which it is called upon to perform. It has gradually been given certain special and typical forms. Every railroad has at least three kinds of locomotives; one to climb steep grades and draw heavy loads, another to dash across the country with its passenger coaches often, for short distances, at the rate of sixty, seventy, eighty, or even ninety miles an hour; a third, neither so strong nor so swift, for mixed traffic. Another type of engine, slow and ponderous, may help drive the oil production of a country half way across a continent.

Man's Most Faithful Servant. The steam engine is the most faithful servant of man. Modern civilization could not be supported without it. For man's benefit it brings materials from the lowest levels of the mine and from the uttermost parts of the earth. It turns the dynamo to light his cities, to propel his street cars, and to run his passenger elevators. It furnishes the power to make the finest

cambric needle, the microscopic parts of a watch, and to forge the gigantic anchor of an ocean liner. It spins for him lace, rivaling the cobweb in its delicacy, and bends the armor plate of a battleship. It plows his fields, grinds his grain, carries his products to market, and makes his clothing. For him it has annihilated distance. It has made it possible for the wheat grower of Manitoba or the cotton planter of Louisiana to exchange his crop for the carpets of Brussels or the cutlery of Sheffield. It has enabled the operatives of those cities to obtain materials for their food from one and for their clothing from the other. It has made ships independent of wind or tide, and eradicated the worst horrors of a stormy voyage. In other times storms might force sailing vessels to beat about for days with hatches battened down, rendering the atmosphere inside stifling beyond description. At such times the aged, the infirm, or the feeble frequently succumbed, and if smallpox or the deadly ship fever were aboard the vessel was frequently converted into a floating pesthouse.

The March of Steam Power. In 1840 steam was in its infancy and constituted only 5 per cent. of the working power of Christendom. At that time about 34 per cent. of the workers of England were engaged in manufactures. Fifty years later steam had increased more than 3000 per cent. The ratio of the workers engaged in manufacture had risen to 54 per cent., and articles were produced for one fourth of the cost of half a century before and more than two and a half times the weight of clothing per capita was produced. The world is better clothed, better housed, better fed than ever before. To-day the sociologist who does not take into account the steam engine as a factor in his studies has an inadequate grasp upon his subject.

Athena, the Greek goddess, who presided over inventions and the arts of peace, was said to have sprung, clad in full armor, from the head of Jupiter, but the steam engine did not spring full-fledged

from the brain of any inventor. St. Peter's, the largest and most famous church in Christendom, was begun in 1163 but centuries were required for its completion. The identity of countless multitudes engaged in its construction has sunk into obscurity, but their work stands. Many a ruler has become famous simply by building one of its thirty-seven chapels. An architect might make a reputation by designing a panel, a window, or a column. The genius of Michael Angelo found a fitting occupation in the construction of its dome. Thus it stands to-day, grand, awe-inspiring, the work of countless hands and many minds. The steam engine has required for its perfection the best inventive talent of more than a score of centuries, and as certain parts of the cathedral are sufficient to immortalize the genius of its constructors so in the working parts of the modern steam engine we may read the names of Hero, Papin, Savery, Newcomen, Watt, Sickles, Allen, Giffard, and Corliss.

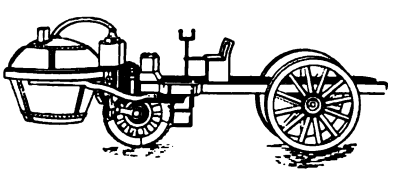
Evolution of the Locomotive.

Like other great inventions, the locomotive was evolved from the workings of many minds and in its development passed through the usual stages of doubt, ridicule, discussion, and adoption. It is so familiar a sight that one is apt to forget that it is of comparatively recent origin. Many persons now living were born before it was introduced into America. People seem to believe, in a vague sort of a way, that it left the hands of Stephenson the perfect machine we know to-day. But it did not spring forth spontaneously; on the contrary it grew to its present proportions and efficiency gradually in response to the pressing demands of an urgent need.

Nearly two thousand years after Hero and his Æolipyle foreshadowed the steam engine, a great philosopher, Sir Isaac Newton, mounted Hero's engine on wheels and the germ of the modern locomotive was started. Newton in 1690 said, "We have a more sensi-

ble effect of the elasticity of vapors if a hole be made in a hollow metal ball and stopped and partly filled with water and then the ball be laid upon the fire until the water boils violently. After this if the ball be set down on wheels so as to move easily on a horizontal plane and the hollow be opened, the vapors will rush out violently one way and the wheels and the ball at the same time will be carried the contrary way." Just as for centuries the philosophers had amused themselves with Hero's Æolipyle, Newton's rude vehicle was spoken of only as a curiosity. One of the instructors in Edinburgh College suggested to Watt in 1769 that he turn his attention to steam carriages. The suggestion did not bear fruit, and the low pressure engine which Watt was engaged in developing would not have been suitable for that purpose.

First Steam Carriage. Nicholas Joseph Cugnot of Paris constructed in 1769 a rude three-wheeled carriage propelled by steam. His engines could keep up steam only about fifteen minutes at a time, and his carriage showed a speed of about two and one fourth miles an hour. It was driven over the ordinary roads and is the common ancestor of the automobile and the locomotive. After a few trials Cugnot's carriage tipped over in the streets of Paris and was locked up in the arsenal for a time by the authorities for fear it would injure some one. Cugnot built another in 1770 which is still preserved in a Paris museum.



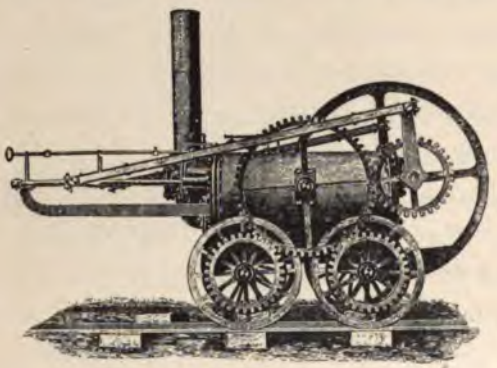
CUGNOT'S CARRIAGE.

Oliver Evans, an American, in 1786 constructed a queer amphibious affair propelled by steam. It was to move along the roads to the bank of the river at the regular ford, swim the stream, climb the opposite bank, and proceed on its way. It was not practicable, but the legislature of Pennsylvania passed a law prohibiting him from running it on the roads of that state.

Captain Richard Trevithick (1771-1833) was the father of the locomotive and the pioneer in the manufacture of high pressure engines. Watt and Newcomen had used their engines at only a few pounds pressure above the atmosphere, and Watt to the end of his days remained a sturdy opponent of high pressure engines. Davies Gilbert, a scientist of high repute and president of the Royal Society, wrote: "Trevithick came to me and inquired with great eagerness what would be the loss of power in working an engine by the force of steam raised to the pressure of several atmospheres, but instead of condensing it to let it escape. I answered, the loss of power would be one atmosphere less the saving effected by discarding the condensing machinery. I never saw a man so delighted."

High Pressure. Trevithick set about improving his boilers and raised the steam pressure to 150 pounds. The legitimate development of this idea has made possible the speedy and powerful engines of the locomotive and the ocean steamer. So remarkable a career may well claim a little of our space. He made in 1796 a model of a locomotive which is yet preserved in South Kensington Museum. Many crude and ludicrous ideas prevailed among the first inventors who turned their attention to the locomotive: one that the cylinders should be in a vertical position that the weight of the atmosphere upon the piston might help hold the engine upon the rails; another that smooth wheels would not adhere enough to the rails to give the engine any power. In 1800 Trevithick and Gilbert, to satisfy the vexed question for themselves, hired the only chaise in the little town of Camborne, drove it to the foot of a steep hill, unhitched the horse and moved the chaise to the top of the hill by turning around the spokes of the wheels with their hands. Trevithick had no further fear that the smooth wheels of his locomotive would not have sufficient adhesion and he at once set to work to build his first steam carriage. His engine had a cast-iron boiler, a wrought-iron

fireplace with a return flue, a vertical cylinder let into the boiler, a feed water heater, and was mounted on four wheels. Draft was secured by exhausting its steam into the chimney and further increased by a leather hand bellows. These facts are worthy of notice, for other inventors, among them the Stephensons, years afterward claimed some of them for their own. On Christmas Eve, 1801, the first trial was made, and an eyewitness has said: "When we seed Cap'n Dick was a-going to turn on steam, we jumped up, as many as could, maybe seven or eight of us. 'Twas a stiffish hill going from the Weith up to Camborne Beacon, but she went off like a bird." Tried a few days later something broke and the carriage was run under a shed while the company adjourned to an inn to regale themselves with roast goose and the drinks of the season. At the close of their festivities they returned to find that a heap of ashes and a few tangled irons represented the shed and the locomotive. When Trevithick's puffing engine appeared one good old lady exclaimed to his partner, "Good gracious, Mr. Vivian, what will come next? I can't compare it to anything but a walking, puffing devil." Trevithick and his partner, Captain Vivian, took out a patent in March, 1802.



TREVITHICK LOCOMOTIVE.

First Locomotive on Rails. In 1803 he built a locomotive as the result of a wager that one could not run over a tramway in South Wales nine miles long and carry ten tons, but it carried the required load and seventy men in addition. In this locomotive, the first that ever ran on rails, he dispensed with the leather bellows and used

a horizontal cylinder turning the exhaust steam from it into the chimney to increase the draft. In 1805 he built a locomotive for a Newcastle colliery but it was diverted from its intended purpose and used to drive an air blast for a furnace. William Hedley, the manager of the colliery, five years later patented an engine and claimed the first application of smooth wheels for steam traction. Hackenworth, who later invented an engine, also worked in the same colliery, and George Stephenson, who built his first locomotive in 1814, was close by. In 1808 Trevithick exhibited in London on a circular track, a locomotive with a speed of twelve miles an hour and carried passengers for a shilling a head. About 1811 a representative of silver mines in Peru came to Boulton and Watt, and asked them to design an engine for use in the Peruvian mines, small enough so that it could be taken apart, and carried over the mountains 15,000 feet above the sea. They declared it impossible. The agent hunted up Trevithick, who not only built several small engines for him but finally followed them to Peru to superintend mining operations. His experiences were varied and highly interesting. This was the period of the revolt of the Spanish colonies against the mother country. Trevithick designed a brass carbine and was impressed into service, together with $20,000 of his money and property. After other adventures and narrow escapes he returned to England, having been absent eleven years. It is computed that his engines and improved methods had saved $2,500,000 to the Peruvian miners, but

GEORGE STEPHENSON.

Trevithick appeared with his clothing worn to tatters and having only a magnetic compass, a gold watch, drawing compasses, and a pair of silver spurs to show for his eleven years' work. During his absence from England other inventors had made some improvements in locomotives and there is a tradition current that Robert Stephenson met Trevithick somewhere in South America and came home with him, greatly to the advantage of the subsequent builder of the "Rocket."

Trevithick was a busy man and locomotives were only one of the many things with which he occupied himself. He began the construction of a tunnel under the Thames river, in fact, progressing until he was within seventy feet of low water mark, when the directors of the company for which he was at work quarreled among themselves and the scheme fell through. He was the first to build the locomotive on a practical scale to run on rails, the first to use flanged wheels, to exhaust the steam into the chimney to increase the draft, to adopt high pressure boilers, and to discover that smooth wheels were sufficient for traction purposes.

The first locomotive intended for passenger service was built in 1821 by Julius Griffiths. Its machinery was intricate and it never proved a success. Up to 1825 the only practical locomotives were used in hauling coal at the mines, but that year the Stockton and Darlington Railway was opened for passenger and goods traffic. The first train was hauled by an engine built by George Stephenson, who acted as engineer on the trial trip. "Off started the procession with a horseman at its head. A great concourse of people stood along the line. Many of them tried to accompany it by running, and some gentlemen on horseback galloped across the fields to keep up with the engine. The railway descending with a gentle incline toward Darlington, the rate of speed was consequently variable. At a favorable part of the road Stephenson determined to try the speed

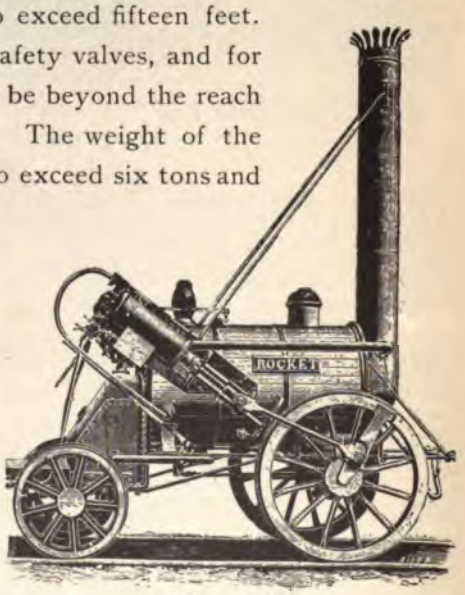
of the engine and called upon the horseman with the flag to get out of the way. Stephenson put on the speed to twelve miles and then to fifteen miles an hour, and the runners on foot, the gentlemen on horseback, and the horseman with the flag were soon left behind.

FIRST TRAIN ON THE STOCKTON AND DARLINGTON RAILWAY (1825), DRAWN BY STEPHENSON'S "NO. 1."

When the train reached Darlington it was found that 450 passengers occupied the wagons, and that the load of men, coal, and merchandise amounted to about ninety tons."

The Rainhill Contest. The famous Rainhill contest, which took place October 6, 1829, for the purpose of selecting the motive power for the new Liverpool and Manchester railroad, was one of the most important events in the history of the locomotive. An editorial in the famous *Quarterly Review* of that period shows the doubt and ridicule that had yet to be removed before the locomotive could be generally adopted. "As to those persons who speculate on making railways general throughout the kingdom, and superseding all the canals, all the wagons, mails, stage-coaches, post-chaises, and, in short, every other mode of conveyance by land or by water, we

deem them and their visionary schemes unworthy of notice. The gross exaggerations of the locomotive steam engine (or, to speak in plain English, the steam carriage) may delude for a time, but must end in the mortification of those concerned. We should as soon expect the people to suffer themselves to be fired off upon one of Congreve's ricochet rockets, as trust themselves at the mercy of such a machine going at such a rate." Some of the conditions of the contest were that the engine must consume its own smoke. It must draw at the rate of ten miles an hour a train of carriages of three times its own weight. The boiler must be able to withstand a test of 150 pounds to the square inch, but the engine must perform its work with a pressure not to exceed fifty pounds. The engine and boiler were to be supported on springs mounted on six wheels, and the height of the whole not to exceed fifteen feet. Each engine must have two safety valves, and for fear of "jockeying" one must be beyond the reach and control of the engine man. The weight of the engine under no condition was to exceed six tons and the preference would be given to a lighter one. The engine and train were to make forty trips of a mile and three fourths each. One eighth of a mile was allowed at each end of the trial course for starting and stopping. The minimum rate of speed for the whole trial was ten miles an hour. John Ericsson, the builder of the Monitor, entered an engine in the competition which to this day his partisans claim was a better one than Stephenson's, but the hot-headed Swede



"ROCKET."

lost his temper and withdrew, unknown to his partner, without making a trial. Five competitors appeared at the trial and one was ruled out because his engine was driven by horse power. The test was too severe for two others. The "Rocket," built by Robert Stephenson, son of George Stephenson, not only withstood the test but did twice as much work as the conditions of the contest demanded. It attained a maximum speed of twenty-four and one fourth miles an hour and maintained an average speed of 13.81 miles per hour. Stephenson's engine won the prize of £500, which had been offered to the successful contestant. As a result, locomotives of the "Rocket" type, only heavier and more powerful, were chosen as the motive power for the new railway.

The First Man Killed by Railroad. The Liverpool and Manchester railroad was formally opened with great ceremony September 15, 1830. But, as if prophetic of its future demands, the Moloch of travel claimed as its first victim William Huskisson, a minister of the cabinet, and Stephenson's "Rocket" has the unfortunate record of being the first to kill a man in a railroad accident.

After Rainhill the development of the English and the American locomotives ran nearly parallel, and to-day there is no great difference between the two national types of engines. A custom peculiar to England originated with the introduction of the locomotive. Shippers were at first backward about patronizing the new system. To encourage trade the railroads offered to deliver freight free to the shipper, instead of leaving it at depots as is customary in other countries. A custom once established in England is not easily changed and free delivery still prevails. At one station the railroad company employs 2,100 men and 800 horses to deliver its freight.

The Pioneer Engines in America. The earliest locomotives used in America were of English manufacture. The "Stourbridge Lion," the first practical one to run on a railroad in the United

States, was built by Stephenson & Co., and arrived at New York May, 1829, and was tried during that year on a portion of the Delaware and Hudson Canal Company's road. The first locomotive made in the United States was "The Best Friend of Charleston." It was built at West Point foundry in New York city and put on the track November 2, 1830. It was not markedly successful. Another pioneer was the "John Bull," built by Stephenson & Co. for the Camden and Amboy road of New Jersey. This locomotive is now in the National Museum at Washington. At the time of the World's Fair at Chicago it proceeded under its own steam from Washington to that city and carried more than 50,000 passengers on a special track at the Exposition Grounds.

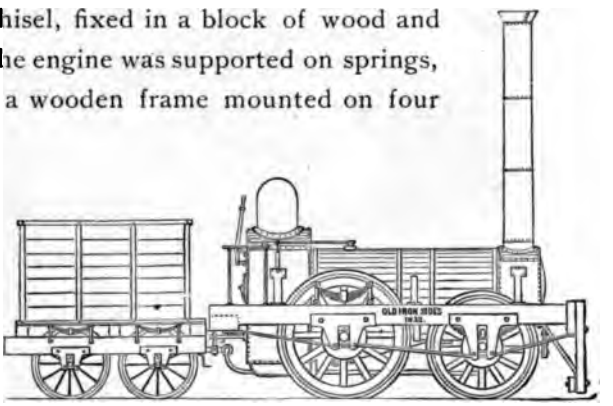
"STOURBRIDGE LION."
The first locomotive to run in America.

The Baltimore and Ohio railroad had intended to use horse power, but Peter Cooper induced the managers to give his engine a trial. Cooper's engine looked like a flour barrel on a hand car. Gun barrels were used for boiler tubes. Mr. Cooper in after years told with great glee how he raced with a gray horse hitched to another car and defeated his four-legged antagonist after a hard contest. Crude as was Cooper's engine it showed the value of steam power. The management of the Baltimore and Ohio railroad advertised that they would hold a contest June 2, 1832, for the purpose of selecting a locomotive. The weight was limited to three and one half tons, the extreme height to twelve feet, and steam pressure of one hundred pounds was allowed. With these exceptions the conditions were about the same as those of Rainhill. A first prize of $4,000 and a

second of $3,500 were offered. At the contest the first prize was won by "The York," built by Phineas Davis of Little York, Pa., and this engine, considerably modified by Winans, became the type of locomotive first used on the Baltimore and Ohio railroad. The question of steam power came rapidly to the front. American inventors gave the matter their attention to such good effect that in 1837 the Norris Works of Philadelphia shipped a locomotive to Austria, and in 1839 Matthias W. Baldwin of the same city filled orders from England. Perhaps no man in America has done more than he for the improvement of locomotives. The history of the American locomotive must include some mention, at least, of the Baldwin Locomotive Works, an establishment that has constructed half the locomotives ever used on this continent.

The First Practical American Locomotive. The Rainhill contest excited interest in America and the manager of the Philadelphia Museum applied to Mr. Baldwin, then a famous machinist, to make for him a miniature locomotive for exhibition purposes. With the aid only of imperfect descriptions and sketches of the Rainhill competitors Mr. Baldwin undertook the task, and April 25, 1831, the engine was put in motion in the Museum. The course was a circular track made of pine boards covered with hoop iron. Two small cars furnished seats for four passengers, and the spectacle attracted large crowds and aroused great public interest. The model was so successful that the Philadelphia, Germantown and Norristown Railroad Company, operating a short line of six miles, gave Mr. Baldwin an order for a locomotive to take the place of the horses they were then using. One can hardly appreciate the difficulties that confronted the manufacturer. There were no suitable tools, no plans or specifications, and almost no literature. This was the situation that confronted Mr. Baldwin when he started to build "Old Ironsides," the first serviceable locomotive of American construction.

The Camden and Amboy road had imported an English locomotive. The parts not yet assembled were lying under a shed at Bordentown, N. J. Mr. Baldwin paid it a visit, made some measurements and a memoranda, and set at work. There were few machinists capable of doing work on such an engine and few blacksmiths able to weld a bar of iron more than one and one fourth inches in thickness. So crude were the appliances that the cylinders, 9½ inches in diameter, were "bored by a chisel, fixed in a block of wood and turned by hand." The engine was supported on springs, and inclosed within a wooden frame mounted on four wheels. The rear pair were driving-wheels, 54 inches in diameter, fixed to an axle bent to form a crank. The wheel hubs were cast-iron, the spokes of wood, and the tires of wrought-iron. The price was to have been $4,000, but some alterations were necessary before it worked well and a compromise price of $3,500 was finally accepted. After much work it was completed and tried November, 1832. There were so many disappointments and annoyances connected with it that Mr. Baldwin declared emphatically, "This is our last locomotive." Yet the plant he founded has since turned out nearly 20,000. After some alterations the "Ironsides" reached a speed of thirty miles an hour. "So great were the wonder and curiosity which attached to such a prodigy that people flocked to see the marvel and eagerly bought the privilege of riding after the strange monster." Even the management of the road



"OLD IRONSIDES."

This locomotive was built by Baldwin in 1832, and at that time represented the acme of locomotive building. Note the contrast with the Atlantic type of locomotive.

did not regard the machine seriously but rather as a curiosity and a bait to attract travel, as is shown by one of their advertisements.

The fascination of locomotive building overcame Mr. Baldwin's resolutions and he soon gave his whole time to it. When the panic

THE ATLANTIC TYPE OF LOCOMOTIVE.
It is this type which is used on the fast runs from Camden to Atlantic City.

of 1837 struck the country he became heavily involved and offered to turn over everything to his creditors. This would have paid them about twenty-five cents on the dollar, but they had such great confidence in the man that they allowed him to continue, and in five years he had paid off every penny of his indebtedness.

First Effort at Speed. The poverty of the country and the low state of iron making made the demand for locomotives limited, but they were constantly improved by many skillful workmen and grew rapidly in size. It is amusing to note that as late as 1842 Mr. Baldwin believed a locomotive built in 1838, weighing thirteen tons, was as large as would ever be needed. To-day just the tender, carrying the coal and water of a large locomotive, weighs six times as much. Great speed was not a consideration and it was not until 1848 that the Central Vermont railroad called particular attention to that quality. They offered Mr. Baldwin $10,000 for a locomotive that could draw a passenger train at the rate of sixty miles an hour. He completed and delivered to them the "Governor Paine," which had only one pair of driving wheels, six and one half feet in diameter, and was the

first fast passenger locomotive. It was advertised that this engine could start from a rest and run a mile in forty-three seconds. It undoubtedly did possess high speed, but had insufficient adhesion to do the great amount of work required of it.

Perfecting the Locomotive. As if in obedience to a general law governing inventions, the locomotive of to-day is a composite structure bearing the different features contributed by the minds that evolved it. Trevithick in 1802 turned the exhaust steam from the cylinders into the chimney to increase the draft of the furnace. Hackworth in 1827 mounted the bell on the locomotive and improved upon the method of using exhaust steam. Seguin in 1828 designed the tubular boiler, which exposed much more heating surface to the furnace fire and greatly increased the steam supply. William T. James of New York in 1832 first used the "link-motion," improved eleven years afterward by the Stephensons. This makes it possible to reverse the engine and to cut off steam in either direction so that it will act expansively. It also prevents the engine from getting "on the center." Stephenson added the steam whistle in 1833. Baldwin in 1834 ground the faces of the joints to make them steam tight instead of packing them with red lead and canvas, as was the custom. When four, six, and eight wheel drivers were applied to the locomotive it was found difficult with so many wheels in a straight line to get around sharp curves. Baldwin patented in 1842 a device by which truck beams connecting the wheels were permitted to move like parallel rulers. A little play, a thirty-second of an inch, was left in the brasses of the connecting rods and the locomotive could turn in a circle 200 feet in diameter. If a railroad track were laid in a circle and two wheels fastened firmly to one axle were rolled about it, since the outer wheel would have to travel the greater distance and one wheel could not turn without the other there would be constant slipping and increased friction. To over-

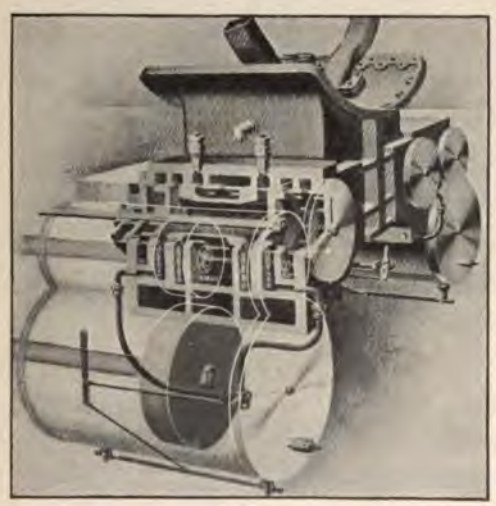
come this, ordinary car wheels are made with the tread (that part of the rim bearing upon the rail) slightly tapering, the outer edge being smaller in diameter than the edge next the flange. The rails are slightly farther apart than the flanges of the wheels. In running around a curve the outer wheel hugs the rail, the flange bears against it and keeps the car from leaving the track. When in this position the outer wheel runs upon that part of the tread having the greater diameter, and the inner wheel, being slightly drawn away from the inner rail, runs upon that part of its tread that is smaller in diameter. By this means the outer wheel covers more distance than the inner wheel, and some friction and slipping are thus done away with. The Giffard injector, which forces feed water from the tanks to the boiler by condensing a small jet of steam, appeared in 1859. Westinghouse perfected his air brake in 1869.

With better tracks the length and weight of trains increased as well as the speed. The value of the coal consumed and the amount carried then became a more important factor, for every ton of coal in the tender of a locomotive displaces a ton of paying freight. The compound stationary engine having proved economical, the principle was applied to the locomotive and seems likely eventually to displace the simple engine.

Compound Engines. In steam engines steam is not turned on from the boiler for the full length of the piston stroke but is "cut off," and the expansive force of the imprisoned steam drives the piston for the remainder of the stroke. A great saving of steam and fuel is thus effected. With a single cylinder steam cannot be expanded to the point of greatest efficiency. So engines are made with two, three, and even four cylinders, and the steam after doing its work in one cylinder is passed into the next cylinder instead of being exhausted into the air. On reaching the second cylinder it is again expanded, and passed into perhaps a third cylinder, and made to do

still more work. Each successive cylinder is made larger than its predecessor, for it has not been found practicable to carry steam at the same volume from one cylinder to another. In some marine engines the steam as it enters the first cylinder has a pressure of 200 pounds to the square inch, and when it is exhausted from the last cylinder, has a pressure perhaps only one pound above that of the condenser. Thus nearly all the available work has been taken out of it.

The Vauclain System is the one most widely used in American locomotives. This system mounts two cylinders on each side of the locomotive and each side forms a complete compound engine. The steam issues from the boiler to the high pressure cylinder shown at the top of the cut. The portion between the upper and lower cylinders is occupied by valves of the piston type. The first part of the valve section is made up of the ends of the valves controlling the admission of the steam from the boiler to the high pressure cylinder. After having performed its work in the upper cylinder, the steam passes to the low pressure cylinder. By this system steam from the boiler can be used in both cylinders at the same time if an emergency requires. This is a marked advantage in starting a heavy train or working it up a steep grade, for if the boiler can furnish the steam, it can be applied at full pressure to four pistons instead of two as in the simple locomotive.



VAUCLAIN SYSTEM OF VALVES.

After the load is started the engine can then be worked compound and do more work with the same amount of steam and coal than a simple engine. The compound locomotive not only saves steam and coal, but, as it exhausts at a lower pressure, it does not pull the coal out of the fire-box and blow it out of the stack in the form of sparks and cinders as does the ordinary single expansion engine. The loss of coal from sparks and cinders varies from 5 to 10 per cent. of the coal fired in the ordinary locomotive. There is none of the noisy puffing about the compound type, usually associated with the idea of a locomotive. Many very careful tests of the compound engines have been made and the saving of coal effected by their use has been found to vary between 14 per cent. and 68 per cent. in the various tests. The Vauclain system is certainly economical. The low pressure at which the steam is exhausted into the chimney gives a mild draft in the furnace that will allow pea coal to be used in place of egg coal, a marked saving in cost. A test was made with two Baldwin locomotives, one of the ordinary type burning egg coal, the other exactly like it except for its compound cylinders and burning pea coal. The compound system showed a saving of 6.9 per cent. in weight and 68.6 per cent. in cost of coal. There are about 40,000 locomotives in the United States alone. If a good compound system were adopted for all, the saving in the coal bill would be enormous.

Quick Locomotive Building. Although locomotives are now much larger and heavier than formerly, the time required for their construction has been greatly reduced. Nearly a year was necessary for the completion of "Old Ironsides." In 1873 the same company turned out a small engine on a "special urgency order" in sixteen working days. In 1889 a test case was made. On Saturday, June 22, Mr. Robert H. Coleman ordered a narrow-gauge "American" type passenger locomotive and tender, which it was agreed should

be ready for service on his railroad in Lebanon County, Pa., by the 4th of July following. The boiler material was at once ordered and was received Tuesday, June 25. The boiler was completed and taken to the erecting shop on Friday, June 28, and on Monday, July 1, the machinery, frames, wheels, etc., were attached and the locomotive was tried under steam in the works. The tender was completed the following day, thus making the record of the construction of a complete locomotive from the raw material in eight working days.

The Baldwin Company. In 1861, thirty years after building its first locomotive, the Baldwin Company had turned out one thousand. To-day its plant has an annual capacity of that number. Mr. Baldwin started in business in a small shop on a narrow alley off from Walnut Street and did much of the work on his first locomotive with his own hands. To-day the establishment has twenty-four buildings, lighted by more than three thousand electric lights, and covering sixteen acres of ground. Between five and six thousand workmen are employed and the principal departments run twenty-four hours a day. Fifteen hundred tons of iron and steel per week are used. One thousand tons of coal per week are consumed to turn the machinery. Such is the fairy-like growth of an industry but seventy years old.

The smallest locomotives are employed for drawing ore cars in mines. Those designed for speed have large driving wheels, usually six and one half feet, sometimes eight feet, in diameter, and but few of them. Engines for hauling heavy loads have from six to ten small driving wheels, sometimes as small as three and one half and four feet in diameter. The greater the weight borne by the driving wheels the greater the adhesion of the wheels to the rail and the more the engine can draw. The engine and boiler are suspended on powerful and heavy but easy and elastic springs to prevent the jar

from the roadbed being transmitted. The life of the average engine is about thirty years.

Increasing the Engine's Power. One of the most conspicuous features of modern locomotives is the enormous increase in their size and weight, in which they seem to be limited only by the power of the rails to support the load. In forty years the cylinder capacity of the passenger type has been doubled. The diameter of the driving wheels has been increased from sixty inches to eighty-six inches. The boiler pressure has been increased from 100 pounds to 210 pounds to the square inch, and engines are now being built which are designed to carry 250 pounds pressure. The tractive power or pull at the draw-bar has been increased from 7,980 to 25,000 pounds. The growth of the 10-wheel or consolidation type, which is used mainly for freight service, has been fully as remarkable.

THE HEAVIEST LOCOMOTIVE IN THE WORLD.

The Largest Locomotive. Locomotives can now be made larger only by making them longer, for the new giant built by the Pittsburg Locomotive Works for the Pittsburg, Bessemer, and Lake Erie railroad has reached the limit in both width and height. This engine weighs 125 tons and its tender weighs 70 tons. The tender alone weighs seventeen times as much as the heaviest locomotive

that competed in the famous Rainhill contest. The engine and tender together weigh about thirty per cent. more than the entire train known as the Empire State Express, the fastest train on the New York Central railroad. Its boiler is 7 feet, 4 inches in diameter at the smallest part, and in it there are 406 tubes each 2¼ inches in diameter, the total heating surface being no less than 3805 square feet. The weight and power of the engine are well shown by the main driving journals, 10 inches in diameter and 13 inches long, while the main crank pin is 8 inches long and has a diameter of 7½ inches. These figures give some idea of the strain to be made upon them. The cylinders are 24 inches in diameter, and the piston has a 32-inch stroke. The piston rods are 4½ inches in diameter.

A horse traveling at the rate of ten miles an hour on a level road can exert 25 pounds of tractive force. This engine can exert a draw-bar pull of 56,300 pounds, or enough to pull 7847 tons of freight on a straight and level track ten miles an hour. If the load this engine can haul were put in good four-wheeled vehicles on the best level ordinary road, it would require 28,563 horses traveling at the same rate of speed on the best macadam roads under the best conditions.

If the horses required to do the work of this single locomotive were hitched two abreast, allowing eight feet for the length of each team, they would reach 21.638 miles. Allowing one driver to each four horses, as in artillery, there would be required 7140 men to drive this great team. The locomotive is handled by two men. Small wonder that improvements in transportation between 1870 and 1893 made wheat 20 cents per bushel cheaper in New York city.

Trevithick's first engine had a speed of about five miles an hour, Stephenson's "Rocket" attained twenty-four and a quarter miles, Baldwin's "Old Ironsides" thirty miles, and the "Governor Paine" of the Central Vermont sixty miles an hour. Man's "iron horse," given its drink of water and the service of its black slave, coal, has

annihilated distance for him. The following were, at the end of the nineteenth century, the world's best records: —

Fast Schedules. Table showing the regular schedule time of some of the fastest short distance trains in the world. They rarely fall short of the schedule, and sometimes exceed it.

NAME OF ROAD	FROM	TO	DISTANCE	MILES AN HOUR
Phil. & Read. R. R.	Camden	Atlantic City	55½	66.6
" " " "	"	" "	55½	66.6
Pennsylvania R. R.	"	" "	59	64.3
" "	"	" "	59	64.3
Midi	Morceux	Bordeaux (Controle)	67¾	61.6
Pennsylvania R. R.	Camden	Atlantic City	59	61.0
Phil. & Read. R. R.	"	" "	55½	60.5
" " " "	Atlantic City	Camden	55½	60.5
" " " "	" "	"	55½	60.5
Nord	Paris	Amiens	81¾	60.5
L. & S. W. R.	Dorchester	Wareham	15	60.1
" "	"	"	15	60.1
Pennsylvania R. R.	Camden	Atlantic City	59	60.0
" "	"	" "	59	60.0
Caledonian R. R.	Forfar	Perth	32½	59.1
Midi	Morceux	Dax	24¼	58.2
"	"	Bordeaux (Controle)	67¾	58.1
Orleans	Orleans	Tours	69¾	58.1
"	Angoulême	Bordeaux	87½	57.6
"	Bordeaux	Angoulême	87½	57.6
Nord	Paris	St. Quentin	95¾	57.4
Orleans	Angoulême	Poitiers	70¼	57.0
Nord	Amiens	Calais Pier	104	57.2
N. Y. C. & H. R. R. R.	Syracuse	Rochester	80	57.1
Pennsylvania R. R.	Atlantic City	Camden	59	57.0
" "	" "	"	59	57.0
" "	" "	"	59	57.0
Orleans	Poitiers	Angoulême	70¼	57.0
Phil. & Read. R. R.	Mass. Ave.	Camden	56.8	56.8
Caledonian R. R.	Stirling	Perth	33	56.5
Phil. & Read. R. R.	Atlantic City	Camden	55½	56.4
Nord	Longuean	Paris	79	56.4
Midi	Dax	Bayonne	31	56.3
"	Bayonne	Dax	31	56.3
Nord	Arras	Longuean	41¼	56.2
Orleans	Angoulême	Poitiers	70¼	56.2
Midi	Morceux	Bordeaux	67¾	56.2
"	Bordeaux	Morceux	67¾	56.2
Orleans	Poitiers	Tours	62½	56.0

The number of trains scheduled for 53, 54, and 55 miles per hour is too large to be included in the list. France easily makes the best showing in the number of high speed trains. The French Northern railroad alone runs 45 trains daily at an average speed, including stops, of over 50 miles an hour, and ten of these are scheduled at from 54 to 60 miles an hour. France has in this list nineteen, United States sixteen, and Great Britain four. German government regulations forbid a speed of more than 56 miles an hour, but it is doubtful if a German train could violate the regulations if it tried. Their fastest trains run between Wittenberg and Hamburg at the rate of 52 miles an hour, between Stendal and Hanover at 50 miles an hour, and between Berlin and Bitterfield at 47 miles an hour.

The following is the schedule time of the fastest long distance trains in the world:—

TRAIN	ROAD	FROM	TO	DISTANCE	TIME	STOPS	MILES PER HOUR
Sud Express	Orleans & Midi	Paris	Bayonne	486¼	8 59	6	54.13
Empire State Express	N. Y. C. & H.R.R.R.	N. York	Buffalo	440	8 15	4	53.33
East Coast	Gt. N. & N. E. Railways	London	Edinburgh	393½	7 45	3	50.77
West Coast	L. & N. W. and Caledo'n Railways	London	Glasgow	401½	8 00	3	50.18

The Empire State Express has to contend with numerous sharp curves and heavy grades. In addition to its regular schedule of four full stops and slackened speed through the city limits, it has twenty-eight regular slow-downs at other points and is frequently checked at grade crossings or drawbridges, yet it almost invariably pulls into Buffalo on time. It was helping to draw this train that engine No. 999 made itself famous. This engine weighs about 62 tons, works at a steam pressure of 190 pounds per square inch, has four driving wheels 86½ inches in diameter, steam cylinders 19 by 24 inches. It was shown at Chicago and that year made a record of a mile at the

rate of 102 miles per hour. Later, it is said to have run at the rate of 112 miles an hour, the highest speed yet attained, but the latter record is not universally accepted.

July 1, 1898, train No. 25, engine No. 1028 of the Philadelphia and Reading railroad, running from Atlantic City to Camden, N. J., drawing five cars and carrying 201 passengers, made an average speed of 81.8 miles per hour for 45 miles, 82.8 miles per hour for 36 miles, and ran one mile in 41 seconds, a speed of 87.8 miles per hour. A copy of the train dispatcher's sheet shows that for the month of August, 1898, the same train, with an average weight of 207.7 tons and carrying an average of 215 passengers, ran for the whole month at an average rate of speed of 71 miles an hour. Engine No. 1028 was built by the Baldwin Locomotive Works and is fitted with Vauclain compound cylinders.

Locomotive No. 564 of the Lake Shore and Michigan Southern railroad, drawing a train weighing 152¼ tons, ran for part of the distance between Chicago and Buffalo at the rate of 92.3 miles an hour, eight miles at 85.44 miles an hour, thirty-three miles at 80.6 miles an hour, and eighty-six miles at 72.92 miles an hour.

A Vauclain compound locomotive on the Northern railroad of France running between Paris and St. Quentin, a distance of 95¾ miles, drew a 108 ton train the whole trip at an average of 67.4 miles per hour. For 50 miles of the trip the average rate was 75 miles per hour.

An Experiment in Speed. Frederick U. Adams, having made a study of fast trains, persuaded the officials of the Baltimore and Ohio railroad to fit six cars, for a special trial, from the tender to the other end of the train. Great care was taken to keep the surface as free from projections as possible. The windows were set even with the car sides and the car sides were covered with matched sheathing reaching almost to the rails. The sheathing was laid horizontally

instead of vertically that the cracks in it might offer less resistance to the air. The vestibules between the cars were carried out even with the car sides. The train weighed 170 tons, was drawn by a 70-ton engine, and made the trip from Baltimore to Washington, including one slow-down, in 37½ minutes. One mile was made in 40 seconds, two miles in 81 seconds, four and one-half miles at the rate of 85 miles an hour. A grade seven miles in length, rising forty feet to the mile, was ascended at the rate of 78.6 miles an hour. The last five miles of down grade from Alexander Junction to Trinidad was made in two minutes and fifty-five seconds, a rate of 102.8 miles an hour. Had the train been drawn by some of the famous engines these figures might have been exceeded.

THE DEVELOPMENT OF THE GAS ENGINE.

Soon after the discovery of the piston, attempts were made to employ it for other powers than steam. Huyghens (1629–1695), famous for his early advocacy of the undulatory theory of light, tried to utilize the explosive force of gunpowder as early as 1680. Illuminating gas was later tried by many.

In 1799 Le Bon, a clever French artisan, patented a gas engine. Considering the condition of the general mechanic arts of that time it was an excellent one. It employed a piston and cylinder, took illuminating gas from a reservoir, mixed it with atmospheric air and exploded it by means of an electric spark on alternate sides of its piston. His engine was automatic and theoretically all right but the high price of illuminating gas and the difficulties of generating electricity rendered his engine impracticable from a financial point.

In 1860 Lenoir obtained a French patent for practically the same engine, but it used 100 cubic feet of gas per horse-power-hour. As gas for the test cost about $2 per thousand feet, and coal $6 a ton, the fuel for the gas engine cost several times as much as the fuel to do the same work by steam.

A Parisian inventor, Hugon, brought out an engine with an improvement on Barnett's idea of lighting the gas from a flame. He introduced a jet of water into the cylinder to be turned into steam by the explosion. Hugon's engine was slightly more economical than Lenoir's.

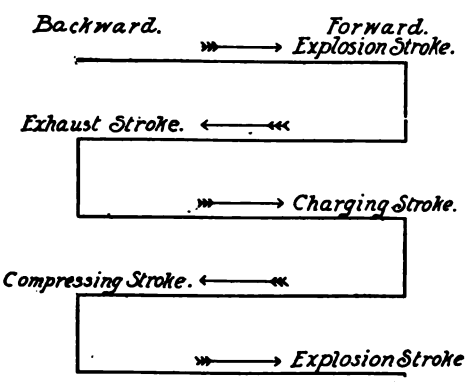
In 1867 Otto and Langen of Cologne exhibited at the Paris exhibition a gas engine which consumed 38 cubic feet of gas per horse-power-hour, and was intolerably noisy. The cost of fuel was still too high.

Brayton in 1872 patented a gas engine, or, more strictly speaking, a hot air engine, for he used largely the expansive force of hot air. This was 18 per cent. more economical than the Otto and Langen engine and worked without any of the distracting noise of the latter.

In 1876 Otto brought out a new engine in which was embodied the famous "Otto cycle" (a definite series of motions constantly repeated), the method in general use to-day. It was found that if the gas and air were subjected to a heavy pressure and then exploded, the resulting force was much greater than under less pressure. The essential feature of the Otto cycle is the application of this principle. It was advocated by Barnett in 1838, tried by several, and successfully applied by Otto in 1876.

How Gas Engines Work. The explosive charge in a gas engine cannot be exploded as often as the piston in a steam engine moves. In a gas engine the propelling power comes in one shock and not a steady pressure. Heavy fly wheels are used which, set in motion by the energy of the shock of an explosion, continue to revolve until the succeeding explosion. There are four piston strokes to each cycle. This means two revolutions of the fly wheel to each explosion. The cycle starts with the explosion of a charge of mixed gas and air in the cylinder. (See diagram.) This drives the piston forward. The energy imparted to the fly wheel revolves the machin-

ery and carries the piston back on the return stroke. On its backward stroke the waste gases are driven out of the explosion chamber. The continuous revolution of the fly wheel carries the piston forward and, during the forward stroke, a fresh explosive charge is admitted into the cylinder. The piston again returns and this time compresses the explosive charge to the desired point, when it is ignited and drives the piston forward again on a new cycle. Various means of igniting the charge have been used: first, an electric spark; next, burning gas jets covered by slide valves; then, a rod heated by friction and the force of the explosion to such a high temperature that it would explode the incoming charge. Recent practice has returned to the electric spark.



How Gas Engines Work.

A very sensitive governor of one of the ordinary types regulates the speed by either limiting the amount of the charge admitted or varying the frequency of the explosions to meet the demand for power. It does it so accurately that in an engine of 130 horse-power working at a speed of 180 revolutions per minute it is impossible for the speed to vary more than one and one half per cent. either above or below the required speed, and under actual working conditions it seldom varies so much as one half per cent. all together. The heavy fly wheels steady the action of the engine and materially aid the governor in its work.

Plants which require much power can connect two, three, or four engines to one shaft and so arrange their explosions that they will follow each other in regular succession, thus giving a more even im-

pulse to the machinery. By using four engines so "compounded," an impulse can be imparted to the shaft at each stroke, instead of at every fourth stroke, as in the single engine.

Gas Engines are of Two General Types: the single acting, in which the power is applied on only one side of the piston; the double acting, in which the force is applied on each side of the piston. The latter are more than twice as powerful.

The gas at the time of its explosion in the cylinder is heated to about 1800 degrees Fahrenheit. The waste gases when they are expelled from the cylinder have a temperature of about 1200 degrees, so the engine turns about 600 degrees of heat into work. The compression of the gas generates so much heat that sometimes it ignites before the proper time has arrived. However, this has been remedied, until even in small engines running at 400 revolutions per minute there is seldom a premature ignition, although the piston when working reaches a temperature little short of a red heat.

The high temperature within the cylinder presents some difficulties in operation and lubrication is difficult, for the heat turns some lubricants into acids which have a destructive effect on the pistons and cylinder. Metals wear fast when heated so hot and the packing requires more attention than in the steam engine, but the gas engine has many features which commend it.

Advantages of Gas Engine. The gas engine uses its fuel through a wider range of temperature than the steam engine, and so is more efficient both in theory and in practice (see Efficiency of Steam Engine), and even a 10 horse-power engine is fairly economical. The gas engine can be started at a moment's notice, it requires no boilers, no firemen, little skilled attendance and can use any volatile hydrocarbon, such as petroleum or gasoline. In using oil it is usually first turned into spray and the spray into gas by the heat within the cylinder. Gasoline vaporizes easily when heated, so is

instantly available. When gas, oil, or gasoline are used there are no ashes to be removed, no chimney giving off disagreeable gases, and the space occupied and the weight of the boiler and furnace are saved and can be used for other purposes.

When the gas engine was first introduced extravagant claims were made for it that were never realized, but the limit of its improvements has not yet been reached.

Of the gases ordinarily used for fuel natural gas or marsh gas stands highest in heat units and is almost ideal for use in gas engines. Coal gas, which comes next, contains about 30 per cent. of marsh gas with twice as much hydrogen. Water gas is formed by bringing a jet of steam into contact with a fiercely burning body of coke or coal. The intense heat separates the hydrogen and oxygen in the steam, which combines with the carbon in the coal to form gas. Water gas has less heat units than coal gas, but is a good conveyer of heat. The heat power of gases measured by carbon stands as follows: pure hydrogen, 4.25; marsh gas, 2.53; coal gas, 1.71; water gas, 0.59. The gas engine has given a wonderful impetus to the manufacture of fuel gas.

Some time and fuel are required to "get up steam" in a steam engine, and if it is stopped for a short time the consumption of coal and the time of the fireman continue, but when a gas engine stops there is no further waste. Since the gas engine is furnace, boiler, engine, and condenser all in itself, there is less loss from radiation than with steam power. A gas engine can burn almost anything from the waste gases of blast furnaces to pure hydrogen gas, including in its range oil and gasoline, and it works well with fuel gas, which can be produced very cheaply.

A 60 horse-power gas engine at Chelsea, England, burning fuel gas, tested for two days used .615 pounds of anthracite coal and .147 pounds of coke, or .762 pounds of fuel for a horse-power-

hour. The best steam power practice is one pound of coal per horse-power-hour.

A Crossley gas engine rated at only 10 horse-power developed 24½ indicated horse-power, on 14.32 cubic feet of Manchester coal gas per horse-power-hour. The gas engine is not yet a satisfactory solution of the power problem, but it gives the greatest efficiency yet attained.

Uses of Compressed Air.

The expression "light as air" is misleading. The bicycle rider realizes the resistance of even a head wind, and its power in motion is utilized by the application of sails to ships, while the destructive force of rapidly moving bodies of air is evinced by the power of cyclones and tornadoes. Light as it apparently is, this envelope rests upon the earth with a pressure at sea level of 14.7 pounds per square inch, and 12.387 cubic feet of air actually weigh one pound.

The thickness of the atmosphere has not been definitely determined. Its action at twilight shows that it will reflect light at a height not to exceed 45 miles. Meteors entering the atmosphere may begin to burn at a distance of 100 miles, and the phenomena of the aurora borealis seem to indicate some sort of a continuity to the height of even 300 miles or more.

Air is essentially elastic, yielding under pressure and occupying less space, while the instant the pressure is removed it returns to its original volume. The idea of compressed air is usually associated in the popular mind with some complex mechanical operation, but nothing is simpler, as may be noted in its common use in the bicycle tire and its compression by the bicycle pump. Fanning a fire with the human breath was probably the first application of compressed air in the industrial arts. From this it has grown until a recent catalogue of compressed air tools and machinery enumerates 327 distinct

uses for which it is now employed, and these range from spreading whitewash to raising a sunken battleship.

Compressed air does not differ in its chemical properties from atmospheric air, but when compressed the heat which it carries is forced into a smaller volume and the temperature rises. This is noticeable even in the rapid working of a bicycle pump. Larger pumps, called air compressors, driven by steam power, usually have a cylinder surrounded with a water jacket to carry away the heat. Compressed air released is quick to seize upon heat from anything with which it may come in contact, to make up for that of which it has been divested. This principle is applied in making liquid air and is one of the things that makes the use of compressed air in mines, the hulls of ships, etc., valuable as a means of reducing temperature.

Advantages in the Use of Compressed Air. Space will permit but a brief mention of some of the uses made of compressed air, for it ranges from furnishing a cushion for an invalid to a Dutton pneumatic balance lock capable of lifting five or six canal boats. In ordinary practice a steam engine is used to drive an air pump (air compressor) which forces air into a reservoir and holds it there at any required pressure until used. To obtain a high pressure it has been found more economical to divide the work into steps, each raising it higher than its predecessor, and delivering it to a cylinder (inter-cooler) where it is partially divested of its heat before delivering it to the next compressor. No additional power is gained by using air in place of steam. The chief advantages are: economy, if the work to be performed is interrupted; convenience, the ease with which it may be carried to places difficult of access, as beneath a freight car, or underneath the keel of a ship; its special fitness, as for work in mines, where it aids in ventilating and reducing the temperature.

A flexible rubber hose has made it possible for a workman to

carry about with him a pressure greater than that at which Watt dared run his steam engines. Many branches of work formerly done with the hand hammer are now performed with a pneumatic hammer.

The Pneumatic Hammer. In the hammer shown in the accompanying illustration, when the trigger is pressed the air from the hose passes through the channel along the side of the hammer and enters the pear-shaped cavity within the piston. Under its impulse the piston rushes downward and strikes a blow upon the hammer head, but at that instant the piston ports are brought opposite openings into the atmosphere and the air within the piston escapes. Meanwhile, the compressed air, not being able to enter the piston, presses against the shoulder running around it and forces it back to the position shown in the cut, when air once more enters into the cavity of the piston and the blow is repeated. A heavy or a light blow may be delivered at the option of the operator, varying with the amount of air admitted.

THE PNEUMATIC HAMMER.

For cutting designs in stone or marble a light, short, quick stroke may be needed. For this class there is a hammer with a light piston and a stroke of about half an inch in length, capable of delivering 7500 blows a minute. Another hammer with a heavier piston, a longer stroke and slower, will deliver 1800 blows a minute and successfully "upset" and "head" a rivet 1¼ inches in diameter. These hammers can be used for a great variety of work, such as riveting, calking, removing "scale," cutting, carving, and dressing all kinds of metal and stone work.

Pneumatic vs. Hand Hammer. A man cannot average for a

whole day's work more than fifteen blows a minute with a hand hammer. The pneumatic hammer places 7500 blows a minute at his disposal, so the amount of work turned out depends mostly upon the skill of the operator, for the speed of the stroke is always more than sufficient to meet any demand. Where pneumatic hammers are used they regularly do the work formerly requiring six, eight, or ten men and at about one quarter the cost. This leaves free three or four men to take up some other kind of work and increases the productive power of the industrial army.

Pneumatic hammers are extensively used for the riveting work of bridges, tanks, boilers, ships, and skeletons of buildings. They enable the power to be brought to the work without the trouble of moving the work to the power. Suppose a rivet to be driven in a ship's deck: it is heated, thrust through the hole, the pneumatic hammer is rested upon it, the trigger pressed, and almost before the hammer can be removed the rivet is upset and headed. A similar instrument armed with a chisel instead of a hammer head removes the superfluous metal, and an instant's work with the hammer smooths the surface. The hammer will do the work of ten men.

Another form of air valve, rather too complicated to be described here, will impart rotary motion and so turn bits and drills to make holes in wood, steel, or rocks.

Castings fresh from the foundry are rough. Hand labor was formerly employed to smooth them. A current of compressed air propelling a blast of sand will do the work of from six to ten men and do it better, for it will reach into nooks and crannies that could not be reached by a tool and it can be operated by a small boy. A pneumatic machine for cutting off stay bolts in boiler work can be easily managed by one man. It will measure accurately and cut 1800 bolts an hour, while 45 bolts an hour would be fast work for hand labor. The sand blast may be used to clean the hulls of steel ships when in dry dock and to remove paint.

Painting and Sweeping by Compressed Air. Nearly all large jobs of painting, like bridges, tanks, warehouses, etc., may be quickly and easily performed by spraying the paint with a pneumatic machine. Greater protection can be given, for the paint by this means can be driven somewhat into the wood and labor that is less skilled may be employed.

A hose pipe and a current of air makes the best possible broom to sweep out a passenger car, for it will reach cracks and corners not accessible by ordinary means. Garden hose is made over an iron bar. When ready to be removed if an attempt were made to pull it off it would be ruined. Compressed air turned in between the hose and the bar stretches it slightly and it can be removed without difficulty. Varieties of hose are now made that can sustain a pressure of a thousand pounds per square inch.

Compressed Air in Mining and Submarine Operations. Compressed air is an ideal application of power in mines where fire damp is present in any quantity. No sparks, better ventilation, cooling of the mine, the outgoing current of air carried with it, the smoke of blasts, are all arguments in its favor.

SUBMARINE USE OF PNEUMATIC TOOLS.

Submarine operations would be impossible without the use of compressed air. The diver and the navigator of the submarine boat both depend upon it to furnish the oxygen necessary to support life. The motive power of the Whitehead torpedo consists of a cylinder containing compressed air at a high pressure. Compressed air, used in the guns of the cruiser *Vesuvius*, threw its dynamite shells over the hills at the entrance to Santiago Harbor.

Compressed air is used in raising sunken ships. Great casks placed near the ships are allowed to fill and sink. Cables are passed under the ships and made fast to the casks. Water is then forced out of the casks by compressed air, so lightening them that they are sometimes able to lift the ship. Another method is to place collapsed air bags within the sunken vessel and then pump them full of air. These displace the water and their buoyant force may enable the ship to float.

In Australia sheep are sheared by clippers run by compressed air motors, and one man can shear one hundred sheep in the time that would be required to shear seventy by the old method.

When the steamer *Paris* stuck fast upon the rocks off the coast nearing the entrance to the English Channel, divers by the aid of compressed air and compressed air machinery removed 15,000 cubic feet of rock which had penetrated her side and held her fast. When the Americans raised the sunken Spanish cruiser *Reina Mercedes*, compressed air drills were used to drill more than three hundred holes below the water line.

Compressed air made the Westinghouse air brake possible, and curiously enough railroad shops have been most forward in its use. Probably the adoption of the air brake and the necessity of air compressors in the shops to test them led naturally to the use of air for other purposes.

On the United States Monitor "Terror." Compressed air is used "for taking up the recoil of the guns and running them out to battery after firing; for rotating the turrets; for elevating and depressing the guns; for all the movements of the breech plug except locking it; for working the telescopic rammer; for blowing out the powder gases when the breech is opened; for picking up and hoisting the ammunition, and for steering the ship."

The gases escaping from the chimneys of locomotives would soon

render the atmosphere in long tunnels unendurable if it were not for the aid of compressed air. By means of air compressors or powerful fans, strong currents of air are forced through and the tunnel ventilated.

Figures on copper, glass, or marble are quickly and inexpensively cut by the use of the sand blast. The glass may be covered with a coat of collodion, gelatin, or wax, and the figure traced upon it, removing the covering from those parts that are to be cut away and leaving the raised portion protected by it. The sand blast is then turned upon it and rapidly cuts away all exposed portions while the elastic coating protects the other parts. Designs in large numbers may be rapidly and cheaply reproduced by making a pattern or templet of thin sheet rubber. A pane of glass exposed to the sand blast is quickly obscured and turned into ground glass wherever the blast falls upon it.

LIQUID AIR.

Within a comparatively recent time the attention of the public has been drawn to the startling phenomena of liquid air and the possibility of its being harnessed for practical work. Air was first liquefied in 1878 by Cailletet in Paris and Pictet in Geneva, but only in minute quantities. By 1886 Professor Dewar of England was able to produce it in small quantities and drew it off into an open vessel. In 1892 in his lectures at the Royal Institution he had a machine that would produce a pint at a time. It is now easily available in considerable quantities. Charles E. Tripler of New York has produced it on such a large scale that it can be carried about and shown at public lectures. The possible application of liquid air outside of the physical laboratory opens up such an unexplored field that some of the most enthusiastic experimenters have been led to claim more for it than they have been able to substantiate. It is accepted as a law that no energy can be created or destroyed. How absurd then to

suppose that more power can be secured from the expansive force of liquid air than was first required to reduce the air to that form! It is unfortunate that such claims have apparently been made for it. Liquid air has already been of service to the chemist. By its aid, hydrogen and helium, the last of the gases, have been not only reduced to liquids, but to solids, and the chemist can now study the physical properties of matter at a temperature more than 200° below the zero of Fahrenheit. Argon, a gas of which but little was known, has by its aid been separated from the nitrogen with which it is usually mixed, and its properties studied. Fluorin, a substance so active that it was almost impossible to obtain it except in combinations, has yielded at the temperature of liquid air, and may now be studied by the chemist.

A Fascinating Subject. If so many curious and marvelous things can be done with liquid air, what a wide field of possibilities is opened up with liquid hydrogen! This subject has a wonderful fascination for the chemist, who strives to attain absolute zero with something of the zest that an explorer searches for the frozen pole. "This subject possesses an attraction for those who are accustomed to look ahead, remembering that the laboratory experiments of one day and generation have often in the past become the foundations of great industries. It took three quarters of a century for Davy's electric arc to develop into the beginnings of commercial arc lighting, and nearly fifty years elapsed after Faraday's brilliant researches in magnetic-electricity, before dynamos became a part of engineering. Yet, Faraday had built a primitive dynamo, and its reversed form was known in primitive types of electric motor. Who would have supposed, when ammonia gas was first liquefied by pressure, that before the close of the century companies would be doing business by sending it about in pipes for refrigeration? Yet, such is the fact."

Were liquid air closely confined and allowed to regain the temperature of ordinary air, it would exert a pressure of about 12,000 pounds per square inch on the walls of the container. Allowed to expand as it regained its heat, it would occupy a volume 800 times as great as it occupied in the liquid form. In this expansion it could do 1,900,000 foot pounds of work for each gallon raised to a temperature of 70° Fahrenheit. This expanding force, used in an engine which could turn it all into useful work in one hour, would do almost one horse-power-hour of work (1,980,000 foot pounds). Used in this manner it would be a heat engine reversed, for it would work, not by giving up its heat, as steam does, but by taking up heat. Gravitation makes no exception in the case of liquid air, which has to pay toll in the form of friction the same as any other power, and the temperature losses of liquid air are greater than those of steam. Further, to prevent the freezing of pipes, etc., heat must be used with it. In any form yet devised the losses amount to at least 50 per cent. A gallon then would do only half a horse-power-hour of work. That is not all. In 1898 it required 15 horse-power-hours of work to produce a gallon of liquid air. The cost of its production must be greatly reduced before it can be generally employed as a motive power, for coal at $3.00 per ton, economically consumed, will produce a horse-power-hour for one fourth of a cent. In other words, it will do work enough in one hour, at the cost of one fourth of a cent, to lift an ordinary locomotive 10 or 12 feet.

Great credit is certainly due to Professor James Dewar for researches in the liquefaction of gases. The first ounce of liquid air which he made cost no less than $3000. In a few weeks he was able to make it for $500 a pint. It can now be made so cheaply that the cost is no longer a barrier to thorough experimentation.

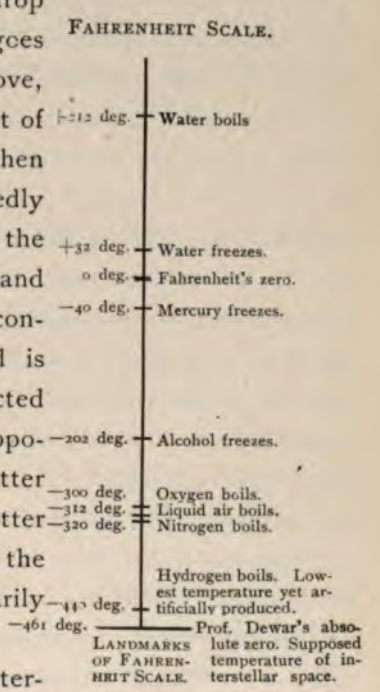
In Charles E. Tripler's process the air with which he starts is not the air that is liquefied. With a powerful engine and air compressor

he pumps air into a reservoir till the pressure is between 100 and 150 *atmospheres*. (An atmosphere is 14.7 pounds per square inch.) Air is drawn from the reservoir for use in the machinery, and constant pumping keeps up a high pressure in the reservoir. The liquefier is a crude looking affair consisting of a tall cylinder covered with heavy wrappings of felt or other materials that are poor conductors of heat. At the base of the cylinder, resting on one face, is a metallic drum, into the upper face of which are screwed a large number of vertical pipes about two inches in diameter. The pipes are open at the top and the contents of the drum can be drawn off by a faucet at the bottom. Small pipes encircle each vertical pipe. The sides of the small pipes nearest the large one are full of minute holes. Compressed air is forced through the holes in the small pipes and strikes in little jets on the larger pipe. The small pipes are closed at the top and connected at the bottom with a pipe leading to the compressed air reservoir. If air is heated it expands, if air is compressed it radiates its heat freely. In making compressed air the heat is carried away by means of water flowing through water jackets surrounding the cylinders. The compressed air from the reservoir, passing through the small pipes, has been largely divested of its heat and, striking upon the vertical pipe, has a chance to expand and takes up all the available heat within the vertical pipe. This reduces the temperature of the large pipe so low that atmospheric air entering at the open tops of the vertical pipes is deprived of its heat and liquefied at ordinary atmospheric pressure.

Cost of Liquid Air. No satisfactory figures are available as to the cost of producing liquid air. Some claim it can be done for a few cents a gallon, and other conservative physicists say it costs five dollars a gallon.

Liquid air may be drawn off into dippers and buckets and poured in the same manner as water is handled. It is almost as much

colder than ice as ice is colder than molten tin. Upon contact with flesh it "burns" like hot iron, and the sores from it are obstinate and require a long time to heal. The hand may be dipped for an instant into liquid air without injury, just as workmen at a furnace dip their hands in molten iron. If a drop of water is let fall upon a hot stove, it goes skipping about without touching the stove, because the heat of the stove turns part of the water into an envelope of vapor. When the hand of the workman is drawn hurriedly through the molten metal the heat of the metal vaporizes the moisture in the hand and so protects the tissues from direct contact with the metal. When the hand is dipped hastily into liquid air it is protected by an envelope of vapor, but for the opposite reason. The hand is as much hotter than the liquid air as the stove is hotter than the drop of water, so the heat of the hand vaporizes enough air to temporarily protect it.



Landmarks of Fahrenheit Scale.

Wonders of Liquid Air. Many interesting experiments can be performed with this substance, which is wonderful only because we are used to seeing it in an entirely different form. With it, alcohol can be made into an icicle in a few seconds; mercury can be frozen and used as a hammer to drive nails. Contained in a teakettle, it will boil vigorously when placed on a block of ice, for ice is 344° hotter than liquid air. Half a pint of liquid air will boil away in thirty minutes. No method has yet been devised that will preserve it for more than a limited time. It is kept longest when surrounded by a vacuum.

Atmospheric air is composed roughly of four fifths nitrogen and one fifth oxygen. In liquid air the nitrogen evaporates the more rapidly, so when the liquid air boils the nitrogen passes off first and the remaining portion grows relatively richer and richer in oxygen, until a piece of steel heated red and thrust into the liquid will burn vigorously. To render this experiment more striking, an operator often pours liquid air into a tapering tin cup, holds the cup in water for a few minutes, when a coating of ice is quickly frozen around it; the ice is carefully removed, and into the hole that inclosed the cup the liquid air is poured. This is so cold that it prevents the ice from melting, and when the nitrogen, as before, has been evaporated from this cup of ice the steel may be burned in the remaining oxygen. This gives an exhibition of great brilliancy and presents the strange spectacle of white hot heat and fierce combustion surrounded by a block of ice without melting the latter. A visitor to Mr. Tripler's laboratory says: "He has an iron tube into which he pours about a quart of liquid air. This tube serves him as a boiler, being heated, not by a fire, but by the warm air of his laboratory, whose heat vaporizes the liquid air. This boiler is then connected with a small steam engine cylinder, which is operated by the air from this boiler, charged with liquid air, just as it would be by steam from a boiler charged with water and heated by a fire."

Limitations of Liquid Air. The plan works excellently, and the engine runs without a fault, but one drawback has been mentioned; it requires more work to make the liquid air than the air can be made to do. The difference is just equal to the amount of power required to run all the necessary machinery, the temperature losses in the process, and the direct leakage from evaporation. The sum of these losses represents the toll that the machinery and material exact in payment for its obliging alteration of form to suit the whim of man.

A small waterfall can be made a big one by digging a pit into which the water may fall, but to keep up the increased power the pit must be pumped dry. The water in falling will not generate power enough to both lift itself out of the pit and run the machinery by which the lifting is done; so practically the pit proves a distinct loss instead of a gain. That is precisely the case with liquid air. Payment in full must be made for any power obtained from Nature, for she never has "bargain days" nor "clearance sales below cost."

Power for Mines.

All mines require power for their operation, and it was the necessity of the English mines that gave birth to the practical steam engine. This, however, although generally accepted and used above, is not always available underneath the surface. The fire from the boilers would certainly cause explosions in some mines, and explosions are frequent enough without inviting them. The water of deep mines frequently contains matter in solution that is deposited as "scale" within the tubes of a boiler and so renders it unfit for use. The smoke and steam would interfere with ventilation and the latter is a problem that has to be carefully worked out, for without a proper air supply the miner can do little work and the better the air the better the work he can do. These objections have usually restricted steam power to use on the surface.

At present electricity furnishes the cheapest means of communicating power for any considerable distance, but some mines are infested with fire damp, and electric wires have an unpleasant habit of giving off sparks when things do not go to suit that whimsical power. One such spark might spread ruin and destruction to the innermost recesses of the mine. Electric lighting is cheap, and with the best connections there is little liability to sparking. It has no exposed flame and does not consume any of the air of the mine.

But there is the constant fear that a globe might break or a current cut across lots (short circuits) and the fatal sparking occur.

Compressed air is free from the defects named but it is an expensive method of transmitting power and the temperature losses and leakages are considerable. However, it has advantages, for it takes pure air just where it is most needed, deposits it at the working face and aids in forcing out the bad air from the mine.

These are a few of the many problems with which the mining engineer has to wrestle. The three methods are frequently combined. The power is generated at the surface by immense steam plants. They also furnish direct power for running and hoisting the surface machinery. Electric currents are generated and carried down the shafts to the level where electricity is to be used. At that point in the mine the electric energy is often employed to drive a motor operating an air compressor and compressed air is carried through flexible hose to the end walls and used by the workmen.

Terrors of Old-Time Mining. Less than a hundred years ago miners went about bearing in their caps lighted candles without anything inclosing the flame. Brought in contact with fire damp (marsh gas, CH_4) disastrous explosions were frequently occasioned. When fire damp constitutes from 6 per cent. to 17 per cent. of the atmosphere it forms a dangerously explosive compound, and freshly exposed coal underground often gives off fire damp in large quantities, a single ton of anthracite coal emitting more than 500 cubic feet.

About 1815 Sir Humphry Davy devised the safety lamp, which consists of a flame inclosed within a wire gauze cylinder. The gauze prevents explosions by absorbing and radiating so much heat that it reduces below the point of ignition the temperature of the gases passing outward through the meshes. A lamp so protected carried into an atmosphere containing from 3 per cent. to 6 per cent. of fire damp shows its presence by the flame growing longer and smoky.

In a higher percentage the gas may penetrate the gauze, ignite at the flame, and occupy the whole position within the gauze cylinder. If subjected to this extra heat for any great length of time or exposed to a draft, the gauze becomes red hot and capable of producing an explosion.

Davy's invention robbed mining of its worst terrors, and probably no single device has saved so many lives, for prior to its invention thousands of lives were annually lost in the mines of Great Britain alone. The safety lamp enables the workman to pass freely through an atmosphere charged with fire damp, lacking but a single spark to hurl him to destruction. Often while he digs the coal that may furnish the cheery fire for a home hundreds of miles away, death lurks in the gloom on all sides, held off only by the frail wire gauze surrounding the flame of his lamp.

Since Davy's time man has labored with remarkable success to devise methods by which he may economically, conveniently, and safely dispossess Mother Earth of her mineral treasures.

Ericsson's Sun Motor.

The sun is the source of all heat and power. Some idea of the immense heat radiated from it may be gathered from the fact that the radiation from each square inch of its surface is on the earth spread over 46,561 square inches, and even when thus attenuated the rays gathered within a small sun glass are hot enough to almost instantly scorch the flesh or set fire to anything inflammable.

Langley has estimated that "if the amount of heat falling on a square centimeter (.15 square inches) were transformed into a lifting force, without any loss whatever, it would raise a cubic centimeter (.06 cubic inches) of water against the force of gravity at the rate of about 4800 feet per minute. A similar computation shows that the heat which the sun, when near the zenith, radiates upon the deck of

a steamship would suffice, could it be turned into work without loss, to drive her at a fair rate of speed."

How long the sun's heat will continue is a matter of conjecture. Whether or not it has continued unchanged is debated and the glacial period has been ascribed by some to a diminution of its heat. It seems certain that when the sun's heat fails the earth will be surrounded by eternal cold and darkness.

In 1876 John Ericsson said: "Upon one square mile, using only one half of the surface and devoting the rest to buildings, roads, etc., we can drive 64,800 steam engines, each of 100 horse-power, simply by the heat radiating from the sun. Archimedes, having completed his calculation of the force of a lever, said that he could move the earth; I affirm that the concentration of the heat radiated by the sun would produce a force capable of stopping the earth in its course." A firm believer in the truth of his theories, he devoted the last fifteen years of his life and $100,000 to experimental work on his solar engine.

Efforts to Harness the Sun. Ericsson's motor is a simple machine and its most striking feature is the immense mirror. This is not flat, nor is it all one mirror. It comprises a large trough-shaped frame with a parabolic curve. If the inside of this trough were covered with a mirror conforming to its curve and exposed to the sun, the rays would all be concentrated in a line at the focus of the parabola. A long tube placed in this would catch on its surface all the concentrated rays from the mirror. These would heat the tube to a temperature of about 600 degrees on a summer day, or a few degrees less on a winter day. If water were to be passed through this hot tube, it would be converted into steam. This was the form of Ericsson's first motor generator. But he soon found that even though all the rays were concentrated by the curved surface, the bending of the rays into small prisms, by the curved surface of the

mirror, caused a loss of heat delivered at the cylinder. This led to the discovery that if heat rays are bent together there is an interference with wave motion that diminishes the amount of heat conveyed. After many experiments he made use of a large number of narrow mirrors arranged side by side following the curve of the frame, but every individual mirror being a plane surface. These did not bunch the rays, and almost the full amount of the heat contained was applied to the heater, very much increasing the efficiency of the motor. The mirror and heater were mounted on a stand and moved by mechanism to keep the mirror at all times pointed directly at the sun. A supply pipe was connected with one end of the heater and at the other end was a pipe for carrying the heated medium, usually water, to the best steam engine obtainable. Flexible pipes were required, and after a time he was able to produce these satisfactorily. Air, in place of water, could be used and heated enough to get a working pressure, inferior to steam, it is true, but a good thing in countries where there is plenty of air and very little water.

More heat can be gathered at midday, because then the sun's rays, falling perpendicularly upon the atmosphere, pass through less than when the sun is near the horizon. The engine can be worked eight hours a day and the energy turned into electricity and used to charge storage batteries. The mirror and heater do not cost so much as an ordinary steam boiler of the same capacity. The engine is, of course, the same as would be used with a steam boiler. The steam boiler is helpless without its fuel. Coal must be mined from the earth, hoisted to the surface, usually hauled a long distance and frequently handled many times before getting to the furnace. Only a skilled fireman can burn it efficiently and all this takes work, time, and money. Not so with the sun motor. As the sun appears above the horizon the mirror is pointed at it, and clockwork mech-

anism moves it to follow the sun's course. The engine once started the machine needs no further attention except an occasional oiling until time to shut down. Stopping the clock brings the mirror to rest, and the rays are in a few minutes focusing on a point that is not in the range of the heater.

Ericsson's engine requires for its highest efficiency a cloudless sky and a tropical sun. The country where such conditions abound is not likely to be thickly populated. "When the world's forests have all been stripped and her coal beds have all been rifled, it is probable that the center of population will be in the center of the Sahara Desert, where the sun sheds his store of power most lavishly. Religions have changed in less time than will be necessary to bring this about, and by that time it is not improbable that the name of John Ericsson, enveloped in the mists of the past, will be revered as the Greeks were wont to reverence Vulcan."

TRANSPORTATION.

Roman Roads — Transportation and Production — First Steam Railroad — Prejudice Encountered — Growth of Transportation — Mileage at Close of Century — How a Railroad is Built — Panama Railroad — Trans-Siberian Railroad — Railroad Accidents — The Block System — Tunnels — Rapid Transit — Passenger Movement of Great Cities — Bicycles — Automobiles — Aërial Navigation — The First Balloon — Military Significance of Air Ships — The First Steamboat — "Great Eastern" — "Oceanic" — "Deutschland" — Steam Turbine — Famous Ship Canals — Canadian Canals — Busiest Canal in the World — Dutton Pneumatic Lock — Relation of Transportation to Progress.

THE primitive man built his own house, made his own weapons, and his wife and children fashioned the rude garments and did the agricultural work. But as association showed that men had varying gifts, one became a hunter, another a fisherman, another a maker of weapons, and the germ of "division of labor" was planted and has grown until to-day our complex industrial system has made us all servants of one another.

Sociologists maintain that man owes much of his progress to association. His wants must have been few indeed when his own efforts could supply them, and the modern breakfast table would look bare and uninviting that offered only the products that the immediate vicinity could afford. With the growth of "division of labor" the variety of products increased and the necessity for a cheaper means of transportation grew apparent and even urgent, for next to the ability to produce is the necessity of distribution.

Trading Promotes Civilization. Conquest usually preceded trade, and the routes traveled back and forth by the armies of the ancient Persians and Egyptians afterward became lines of travel over which passed the rich goods of the Orient. It was trade that built up those opulent cities of the Mediterranean: Tyre, Carthage, Alexandria, Genoa, and Venice. With the development of civilization regular routes of travel grew, over which passed the caravans of traders, merchants, and pilgrims associated for security, journeying from one country to another, and Asia Minor was for Europe the gateway to the East. The religion of Mohammed changed the course of the world's trade, for his followers were fanatically hostile to the western nations and the spread of Mohammedanism across Western Asia cut off the caravan trade with the Orient. Portugal, the leading maritime nation of the fifteenth century, searching for another route, sent Vasco da Gama around the Cape of Good Hope, discovered by Diaz, and established a water route to India. It was the needs of commerce, a new and shorter route for the trade of India, not alone the spirit of discovery, that Columbus urged as a reason for his voyages of discovery.

It is an important consideration that armies be readily supplied with provisions and munitions of war. Genghis Khan (1162-1227), with his armies conquering Northern China and founding the Mogul Empire, stopping to plant crops and harvest them, furnishes a marked contrast to the rapidity with which Western civilization lately organized and rushed its rescuing columns to Pekin. The Romans, for military purposes, threw across their subjugated colonies a network of magnificent roads, some of which endure and give excellent service at the present time.

Transportation Creates Trade. "Down to about the twelfth century each village, as a rule, formed an independent community, having its own blacksmith, its own miller, and its own craftsman, as

far as handicraft was developed, while the operations of spinning and weaving were carried on by each household for itself. Certain days were set on which the country people would carry their goods to town and make their purchases. These market towns became more and more the residence of craftsmen, and the place in which the various forms of manufacture first developed. Stores or shops, in the modern sense, did not as yet exist. The farmer sold his produce at the market and bought his goods of the craftsman. But the first step toward commerce had been taken, for he had ceased to depend upon himself for all his supplies."

With the gathering of craftsmen into towns and the development of the factory system transportation was quickened. The lessened cost at which goods could be produced at industrial centers left a margin of profit that could be paid to a carrier to wider markets. Transportation furnished the means of that exchange of products which rendered the division of labor possible, and each improvement in transportation facilities helped to reduce the cost of carrying freight, and this in turn stimulated increased traffic and brought to the consumer products that otherwise would not have been available for him. As manufacturing towns grew and their products increased in value they became wealthy enough to give to the construction of roads and the bettering of means of communication.

Roman Roads.

The skill of the Romans as road builders aided them in maintaining their military supremacy. During the golden days every road literally led to Rome, for, outside the limits of the Roman world, there were no roads worthy of the name; while within its limits every highway was but part of a system which centered in the Appian Forum. From the Wall of Antoninus in Britain, to Jerusalem, was 4080 miles; and to the extreme limits of the empire on the Eu-

phrates 4500 miles, all included in the system. These roads were of a military character, and no country was considered by the Romans as conquered until roads had been constructed. Their strategic value is shown by the fact that in every provincial insurrection the rebels tried first to destroy the roads and bridges. Road making was the common toil of the slaves and criminals, and in newly acquired provinces the whole male population were often temporarily forced into the service.

Every mile was marked by a milestone, and at every fifth mile was a posthouse where forty horses were always kept in readiness for imperial service. The imperial messenger, using relays, could travel 100 miles or more in a day.

In country districts nothing affording concealment for robbers was allowed within 200 feet of the road. Roads passing where the loyalty of the people was open to suspicion had a stone wall breast-high built on each side, affording quite a fortress. From city to city the roads usually ran in a straight line, property being condemned without much regard for the rights of its owners. Military requirements took precedence over every other claim. Natural obstacles did not deter the road builder, who tunneled mountains and filled morasses with stones and earth. Grades were no serious objection, for travel was almost entirely on foot or on horseback, wheeled vehicles being little used in the country.

Roman Roads were Built to Last. When the line of a road was determined, on each side of the road trenches were dug and one foot of the earth between removed. The earthen floor was then packed firmly and the trenches and floor filled to the ground level with concrete. The whole was firmly packed and allowed to solidify. Larger stones were next placed on this base and the interstices filled with mortar and the road given another layer of concrete, like the bottom layer. The towns and cities had in addition a top layer of

granite or basaltic blocks, cut to fit accurately and making a smooth and level roadway. The typical Roman road was practically a mass of solid stone from fifteen to twenty-five feet wide and three feet or more thick.

The Appian Way, the finest road the Romans built, has been in constant use for more than 1800 years. The top layer of the road is made of hexagonal blocks of granite, so accurately fitted that even to-day it is not easy to detect the joints.

Quick and Cheap Transportation has had a potent influence on the morality of commercial transactions. The old proverb, "Let the buyer beware," has come down from the times when the buyer and the trader perhaps saw each other but once in a lifetime. The trader and manufacturer now depend on the buyer's steady favor and prepare their goods with special care to suit his tastes and requirements.

The immense gain by the application of steam to railways and navigation cannot well be estimated, but the fact must not be lost sight of that it was increased productive power that stimulated transportation. The steam engine did its first work in a coal mine, the first locomotive hauled the coal from that mine to a market, and as manufacturing grew under the stimulus of its new servant, the needs for quicker and cheaper transportation became more urgent. The locomotive and steamship came to supply the demand.

Transportation Feeds England. If an example of the necessity of adequate transportation is desired, it may be remembered that without it England would starve to death in a few months, for her agricultural industries so far fail to produce what is necessary to feed her own people, that she is required to import food supplies for 285 days of the year. This point has an especial military significance, as is evidenced by the enormous navy she feels called upon to sustain, to guard her lines of food supplies. Modern methods have made it

possible to supply mutton chops from Australia for the London breakfast table, cheaper and quicker than the same could formerly have been obtained from the Highlands of Scotland. Australian fresh beef carried in refrigerators was furnished to American soldiers on the firing line in the Philippines.

An Example of Mechanical Progress. It would be difficult to find a town offering a better illustration of what society owes to mechanical progress than Manchester, England, that typical hive of systematized human industries. Manchester was early famous as a manufacturing center, and in Queen Elizabeth's time it was spoken of as "surpassing neighboring towns." In 1724 it was said to be "the largest, most rich, populous, and busy village in England." It has what is believed to be the oldest free library in the kingdom, and is probably the birthplace of the present factory system and methods of modern transportation, for it was here that Stephenson's railroad had its famous contest with the Duke of Bridgewater's canal. It also possesses great interest for the student of municipal government, for it owns its own markets, gas works, water works, street railroads, and numerous valuable electrical and water power privileges. It derives a large income from its corporate property and uses it for public improvement and to reduce taxation. In 1757 this city had a population of 20,000 inhabitants, of whom an unusually large proportion were engaged in manufacture. Great difficulty was frequently experienced in securing the necessary raw materials, cotton, wool, coal, and iron, as well as food supplies for the operatives. The country immediately surrounding it could not supply all its demands and the nearest seaport was Liverpool, thirty-five miles away. Connecting the two cities were excellent roads, and freight was hauled in wagons by horses from one to the other at a cost of $10 to $12 per ton. For a time it seemed as though the factory system had outgrown the transportation system that supplied the raw materials for its finished

products. To reduce this freight rate, which greatly increased the cost of living, cost of materials, and so the cost of the finished products of Manchester's factories, the Duke of Bridgewater undertook to build a canal connecting the two cities. The cartage companies recognized this as a rival and left no means unturned to incite opposition and provoke ridicule. The canal was dubbed "The Duke of Bridgewater's folly," but he was a man of indomitable courage and completed it after sixteen years of strenuous effort which is said to have shortened his life. When completed, the cost of carrying a ton of freight from Liverpool to Manchester fell from $10 or $12 to $2. Trade felt the stimulus, and in forty-five years the two cities had increased in population and wealth more than 300 per cent., and Liverpool took rank as the second commercial town, and Manchester as the first manufacturing town in the world. But with this great increase the factory system again outstripped transportation and Manchester freight often waited at its seaport, longer than it took to carry it from New York to Liverpool. Two other canals were built and taxed to their utmost. Manufacturing interests increased and the resulting prosperity demanded better service. The Liverpool and Manchester railway was chartered in 1828 and it was intended to use horses for motive power, but George Stephenson interested the directors in steam power and they offered the prize for the Rainhill contest, with what result the world knows.

In the early days of the American Republic the problems of transportation and communication were deemed of the utmost importance, and engaged the best minds of the country. It then cost $100 to move a ton of freight from Buffalo to Albany, and $5 to carry a barrel of salt from Pittsburg to Philadelphia. The locomotive had not been invented and the mouth of the Mississippi river was controlled by a power none too friendly. The free navigation of that stream was necessary to the welfare of the Western colonies,

for it furnished their only cheap means of communication with the seaboard. The states were encouraged to build turnpikes and the United States government began the construction of a public road from Washington via Wheeling, Columbus, and Vandalia, to the Mississippi river. The necessity of better means of communication was recognized by all. "The subject was a favorite one with Washington, and he looked at it from both a commercial and a political point of view. What we most needed, he said in 1770, were easy transit lines between east and west, as 'the channel of conveyance of the extensive and valuable trade of a rising empire.' Just before resigning his commission in 1783 Washington had explored the route through the Mohawk valley, afterward taken first by the Erie canal and then by the New York Central railroad, and had prophesied its commercial importance in the present century. Soon after reaching his home at Mount Vernon, he turned his attention to the improvement of intercourse with the west through the valley of the Potomac. The east and west, he said, must be cemented together by interests in common; otherwise they will break asunder. Without commercial intercourse they will cease to understand each other, and will thus be ripe for disagreement. It is easy for mental habits, as well as merchandise, to glide down stream, and the connections of the settlers beyond the mountains all center in New Orleans, which is in the hands of a foreign and hostile power. No one can tell what complications may arise from this, argued Washington; 'let us bind these people to us by a chain that can never be broken;' and with characteristic energy he set to work at once to establish that line of communication that has since grown into the Chesapeake and Ohio canal and into the Baltimore and Ohio railroad."* The need was urgent enough, for in 1814 Robert Fulton estimated that it cost $100 to move a ton of freight by means of

* John Fiske's "Critical Period of American History."

horses and wagons three hundred miles on the highways of Pennsylvania and Ohio. The transportation system between Philadelphia and Pittsburg was the most primitive. "For several years after the peace of 1783, there was nothing but a horse path over the mountains; so that salt, iron, powder, lead, and other necessary articles had to be carried on pack horses from Philadelphia to Pittsburg. As late as 1794, the year of the insurrection, so bad were the roads that freight in wagons cost from $5 to $10 per 100 pounds; salt sold for $5 a bushel; iron and steel for fifteen to twenty cents a pound in Pittsburg." *

No longer ago than 1809 freight going from Lake Ontario to Lake Erie and west had to be hauled from the mouth of the Niagara river to the head of the falls, a distance of twenty-eight miles. The regular charge for this was seventy-five cents for a bushel of salt and $10 for a ton of general merchandise. It is easy to see that the costs would mount up with frightful rapidity when goods had to be carried by such methods any considerable distance. The humblest laborer of to-day enjoys what would then have been unparalleled luxury for people in comfortable circumstances, while the economy and self-denial necessary for those less fortunate can hardly be imagined.

Primitive Methods in South America. Some of the primitive methods yet employed in the South American states are interesting. The transportation system of Colombia contrasts sharply with improved methods and shows the condition of affairs where every pound of freight must be carried either by mule or man power. The chief port of entry of Colombia is Barranquilla, on the Magdalena river. The city is eighteen miles from the coast and bars obstruct navigation below the city. A narrow gauge railroad eighteen miles long connects the city with the coast and runs out on a steel pier over 4000 feet long, at the end of which there is 26 feet of water at low

* Eagle's "History of Pennsylvania."

tide. This pier is remarkable as being one of the longest three in the world. It annually receives 34,000 tons of freight and discharges 23,000 tons. Freight intended for the interior of the country is put up in packages of about 125 pounds, two packages making a mule load. If the packages are heavier, they are carried by man or woman power, and as the weight of the package increases the prices go up at an amazing rate. The average man load is 330 pounds, and the load most frequently carried by the woman packers is no less than 220 pounds. One of the packers recently carried an organ, packed in its case, on his back for 90 miles inland. When the package is too heavy to be thus packed, it is dragged along the rough and treacherous mountain trails by means of a rope and windlass, and the progress is slow indeed. One piece of machinery for the government mint was five years on a 100 mile trip. Man packing costs $10.18 per ton-mile in paper money; mule packing from 65 cents to $3.00 per ton-mile. It recently cost a contractor $1500 to transport twelve 20-foot iron rails over 90 miles of mountain road. A sack of coffee weighing one sixteenth ton, carried from the plantation where it is grown to its market in New York, costs for mule-packing to the river $8.50 paper money. For 500 miles down the river to Barranquilla, it is carried by boat for $1.92 and the 18 miles of railway to the dock costs 33 cents. This is a total of $10.75 in paper, or $4.30 in gold, for the first 598 miles transportation. A steamer then takes it and delivers it in New York, 2000 miles away, for only 40 cents. A ton of freight can be brought from Europe, 5500 miles, and carried 600 miles up the Magdalena river for $24. But His Excellency, the mule, demands $64.00 to carry it the remaining 90 miles inland to the capital.

RAILROADS.

The primitive method of packing freight on the back of a horse is expensive, for it does not allow him to apply his strength to the

best advantage. Placed on wheels, he can take three times as much over a poor earthen road, nine times over a good macadamized road, twenty-five times over a plank road, thirty-three times over a stone trackway, and fifty-four times over a good railway, as he can carry on his back. The foregoing is about the order in which railway construction using the horse as a motive power developed. In the reign of George III., the inland transportation facilities of England were at such a low ebb that the old Roman roads furnished the best routes of travel.

It is uncertain when railways first came into use, but the plan is old, and stone tramways have been attributed to the Romans. Their tracks were said to have been made of two lines of cut stones. Smiles's "Life of George Stephenson" states that in 1630 Master Beaumont laid down wooden rails from his coal pits near Newcastle to the river side. In 1738 Jessop introduced at Loughborough the cast iron edge rails and cast flanges upon the tires of the wheels so as to keep them on the track. In 1800, at Little Eton, Derbyshire, Outram used stone sleepers for his railroad, and from his name is derived the term "tramways."

The application of the flange to the car wheel was a great improvement. The manufacture of wrought iron improved until rolling mills were able to turn out long strips called "strap iron" and these were spiked to the top of the wooden rails.

As loads grew heavier and requirements greater the "T" rail was introduced, on top of which the wheels ran. The rail was held in place by brackets called "chairs," spiked to crosspieces called "ties."

The First Steam Railway was that at Pen-y-Darran in South Wales, nine miles long and covered with cast iron plates. On this a Trevithick engine was employed to haul coal. The Stockton and Darlington railway, opened in 1825, was a coal road on which it was

intended to use horses, but George Stephenson constructed locomotives weighing about twelve tons that under favorable circumstances were able to carry a load with a speed of seven or eight miles an hour.

Stephenson's success on the Stockton and Darlington railroad inclined the managers of the Liverpool and Manchester railroad to listen to him favorably. After the Rainhill contest, October, 1829, preparations were made to equip their road with Stephenson's engines. It was opened with considerable ceremony September 15, 1830, and William Huskisson, a prominent statesman, was struck by a locomotive and mortally injured. The "Rocket" carried the dying statesman to his home fifteen miles, in twenty-five minutes, at one point attaining a speed of thirty-six miles an hour. There was no longer any doubt as to the capability of the locomotive, and modern railways may be said to begin with the Liverpool and Manchester road. Stephenson and the managers had not succeeded without a hard struggle. The railroad met as violent opposition from the canal men as they had met from the cartage companies, for if the newfangled steam locomotive were able to make the trip in four hours, while it took the most rapid canal boats fourteen hours, the welfare of the canals would be seriously jeopardized. Present personal interest again gained the ascendency over public welfare, and the struggle of Stephenson to accomplish his plan is a matter of history. Even in Parliament it was argued that if the new method of travel were to be at all extensively used, such people as stage owners, teamsters, and inn keepers would be deprived of their means of livelihood, and national disaster would swiftly follow. However, the conservatives had to "look out for the engine," for the railroad reduced the freight rate between Liverpool and Manchester from eight shillings to less than one shilling a ton, and gave an electrical impulse to transportation throughout the civilized world.

EARLY TRANSPORTATION.

The First Passenger Cars on the Liverpool and Manchester roads were crude enough, and not as comfortable as an ordinary flat car now used for hauling freight. They had no roofs, and as they were without springs the constant jar of the road soon shook them to pieces, until, as a matter of economy, springs were added.

In the early days of steam railroading it was customary for a traveler to drive up in his own private coach, remove his horses, have the coach and its passengers transferred bodily to the railroad carriages, connect them to the train and complete the journey in his own coach. The custom left its imprint upon the standard passenger "coach" of the English roads, which for many years bore a close resemblance to the stagecoach of highway travel.

In America facilities for traveling were even worse than in England, for the country was new, thinly populated, and so poverty-stricken that but little attention had been paid to internal improvements. In the palmy days of stagecoaching the fare from New York to Albany was $12, and from New York to Boston $15. When light coaches, called "flying machines," put on the road between New York and Philadelphia, were able to make the trip in two days it was spoken of as marvelous. The express trains of today cover the distance in two hours. In 1865, one Salt Lake City merchant paid $150,000 a year to bring his goods from the Missouri river. The same year transportation cost the United States government in Utah $1,524,119, and the price of a bushel of corn delivered at Fort Kearney was $5.03, Laramie $9.26, Colorado $10.05, Salt Lake City $17.

Judge Tait of Ohio says: "I paid the sum of thirty-two dollars and some cents to be carried from Wheeling to Cincinnati, in 1835, a sum which was by no means insignificant to a somewhat impecunious young lawyer who had just been admitted to practice."

Difficulties of Early Travel. About the beginning of the cen-

tury, in describing the traveling between Boston and New York, President Quincy of Harvard College said: "The carriages were old and the shackling and much of the harness made of ropes. One pair of horses carried us eighteen miles. We generally reached our resting place for the night, if no accident intervened, at ten o'clock, and after a frugal supper went to bed, with the notice that we should be called at three next morning, which generally proved to be half past two, and then, whether it snowed or rained, the traveler must rise and make ready by the help of a horn lantern and a farthing candle and proceed on his way over bad roads, sometimes getting out and helping the coachman lift the coach out of a quagmire or rut, and arriving in New York after a week's hard traveling, wondering at the ease as well as the expedition with which our journey was effected."

The first American railroad was built by Thomas Lieper, 1809, near Bull's Head Tavern, Philadelphia. The line was short, but the next year he had a road three fourths of a mile long leading from his quarries to the landing place on Crum Creek. He estimated that this had cost him $1500. Progress was so slow that what is probably the first iron railroad in America was very appropriately built to transport the granite required for the Bunker Hill monument. This road ran from the granite quarries of Quincy, Massachusetts, to the docks at tide water. It was begun in 1826 and completed in 1827, using granite blocks for ties, on top of which were placed wooden rails faced with a strap of rolled iron.

No longer ago than 1827 the Boston *Daily Advertiser* published a series of articles entitled "Remarks on the Practicability and Expediency of Railroads from Boston to the Hudson River, and from Boston to Providence." These articles, as read in the light of modern achievements, have a certain tinge of the ludicrous but they are also marked by sound common sense. They express a clear recognition of the necessity of a better means of transportation, though

some of the expedients they suggest are, to say the least, unique. Horse power is recommended as a motive power, and the steam locomotive only hinted at as a remote possibility. The possibilities of Massachusetts as a manufacturing state were stated and followed by the statement that while the population of the United States as a whole had increased 150 per cent. in thirty years, that of Massachusetts had increased only 30 per cent. This was attributed to the fact that there was no adequate means of inland transportation.

The value of railroads was early recognized, many ridiculous plans for motive power for them advanced, and some amusing devices tried. "On the Baltimore and Ohio ran first of all a little clapboarded cabin on wheels, for all the world like one of those North Carolinian mountain huts, with the driver perched on top of the front portico, because the motive power then was one horse in treadmill box."

First American Locomotive. In 1819, John and Maurice Wurts, two Philadelphia Quakers, undertook to supply New York with Lackawanna coal, and out of this grew the Delaware and Hudson canal, 105 miles long, connecting the two rivers. For some time coal was drawn in wagons by horses from near Carbondale to the canal at Honesdale, and shipped thence to New York. Finding this method too slow and expensive, they built a railroad sixteen miles long from the mines to Honesdale and hauled their coal in cars drawn by horses. This trade increased, and the Delaware and Hudson Canal Company became interested in the experiments with locomotives then being conducted in England. In 1828, John B. Jervis, chief engineer of the company, sent his assistant, Horatio Allen, to England to study the subject. In May, 1829, Allen returned with a locomotive. The railroad track consisted of long hemlock stringers or rails 6 by 12 inches in section, on which were spiked bars of rolled iron 2¼ inches wide and ½ inch thick. The rails were sup-

ported every ten feet by sticks of timber. On this track the engine which had been named the "Stourbridge Lion" was tried August 9, 1829.

"The road crossed the Lackawaxen river after a sharp curve, on a slender hemlock trestle, which it was believed would not support the engine. Allen was besought not to imperil his life with it. He knew there was danger, but, anxious to connect his name with the first locomotive in America, he determined to take the risk. He ran the engine up and down along the dock for a few minutes and then invited some one of a large assembly to accompany him. No one accepted, and pulling the throttle wide open he said 'good-bye' to the crowd and dashed away from the village, around the abrupt curve, and over the trembling trestle amid deafening cheers, at the rate of ten miles an hour." Mr. Allen lived to take a prominent part in the improvement of locomotives and the development of railroad systems. In speaking of the trial on the Carbondale and Honesdale road he said, "I had never run a locomotive nor any other engine before; I have never run one since." The "Stourbridge Lion" was attached, after the trial, to trains of coal cars and drew them satisfactorily on the dock but could not be employed to advantage on so light a roadbed, and the latter could not be fitted to the engine on account of the expense required. Finally it was taken to pieces, its boiler carried to Carbondale and put into the foundry where it was still in use in 1890. Such was the career of the first locomotive on the American continent.

Short lines of railroad began to spring up both in England and in the United States, and the queerest ideas prevailed concerning them. "The people at first thought of the railroad merely as an improved highway which should charge tolls like a turnpike or canal, and on which the public should run cars of its own independent of the railroad company itself. In England long sheets of tolls were published,

naming the rates under which the use of the roadbed should be free to all." The people of New England had no more accurate conception, for George Ticknor Curtis said, in 1880: "I remember that the ideas of the first projectors of railroads in New England and of the public, as to the use that would be made of them, were exceedingly crude. The earliest charters granted in Massachusetts contain traces of an expectation that the company would lay down the rails and that the public would somehow drive their own carriages over them, the proprietors having the right to exact tolls." The lines were not built according to any harmonious plan. As late as 1847 there were in England seven hundred chartered railroads, averaging about fifteen miles each in length. What is now the New York Central and Hudson River railroad constituted sixteen separate and distinct organizations, incurring numerous trans-shipments of freight, delays, expenses, multiplicity of offices, division of responsibility, and all attendant evils. The public need eventually brought about in the fifties consolidation of the many warring, jarring, jangling interests. This consolidation was not due to the wisdom of legislators, and was due only in a small measure to the personal influence of railroad managers, for it took place about the same time all over the world. It is needless to say it reduced operating expenses and gave better service to the public. It seems in a way to have foreshadowed the great combinations of capital now being formed.

Growth of Rail Transportation. Western Pennsylvania, during Washington's administration, suffered for the lack of adequate transportation. The cost of carrying grain by horse and wagon one hundred miles was equivalent to its price on reaching market. The same grain turned into whisky occupied less bulk for its value and could be easier transported. The tax upon whisky was keenly felt because it was a tax upon about the only exchangeable product of the people.

A good system of transportation would have removed the exciting cause and modern methods have made its recurrence impossible.

Pennsylvania, with the first American steam railroad to her credit, continued their construction with commendable zeal, and in 1835 had two hundred miles, about one fourth the whole mileage of the United States.

"When the roads forming the line between Philadelphia and Harrisburg, Pa., were chartered in 1835, and town meetings were held to discuss their practicability, the Hon. Simon Cameron, while making a speech in advocacy of the measure, was so far carried away by his enthusiasm as to make the rash prediction that there were persons within the sound of his voice who would live to see a passenger take his breakfast in Harrisburg and his supper in Philadelphia on the same day. A friend of his on the platform said to him after he had finished: 'That's all very well, Simon, to tell the boys, but you and I are no such infernal fools as to believe it.' They both lived to travel the distance in a little over two hours."

The Baltimore and Ohio was the first road undertaken in the United States for the transportation of passengers and freight on a large scale. It was begun in 1828, and on July 4th of that year Charles Carroll, whose life seemed to form a connecting link between the political revolution of one century and the industrial revolution of another, laid the first rail. In 1831 the Baltimore and Ohio offered premiums of $4000 and $3500 for competing locomotive builders, and the winning locomotive, made at York, Pa., was carried on wagons over the turnpike roads from there to Baltimore, Md. (See Locomotives.)

By the close of the year 1835 the Baltimore and Ohio had attained a length of 115 miles. Peter Parley, who wrote school books for our grandfathers, describing Maryland, says: "But the most curious thing in Baltimore is the railroad. There is a great trade between

Baltimore and the states west of the Alleghany mountains. The Western people buy a great many goods at Baltimore and send in return a great deal of Western produce. There is, therefore, a vast deal of traveling back and forth, and hundreds of teams are occupied in transporting goods and produce to and from market. Now in order to carry on this business more easily the people are building what is called a railroad. This consists of iron bars laid along the ground and made fast, so that carriages with small wheels may be run along them with facility. In this way one horse power will be able to draw as much as ten horses on a common road." It was on this railroad that Peter Cooper in 1829 conducted his experiments with his little engine and had his race with the gray horse, and, singularly enough, Peter Parley speaks of such an animal.

In seven years after the beginning of the Baltimore and Ohio, South Carolina had in operation the longest line of railroad in the world under one management, the Charleston and Hamburg, 137 miles in length. New York, New Jersey, and Massachusetts had about 100 miles each.

Beginnings of Railroad Consolidation. The Mohawk and Hudson (Albany and Schenectady) was opened in 1831, the Saratoga and Schenectady in 1832, the Rensselaer and Saratoga in 1835. What is now the New York Central had in 1836 been completed from Albany to Utica, and by 1842 it reached Buffalo by a devious route. In 1851 the line was completed from New York to Albany and soon all the different systems from New York to Buffalo were consolidated under one management. By 1851 the Erie had been completed from the Hudson river to Lake Erie. The Lake Shore and Michigan Southern, connecting the New York Central with Chicago, was opened in 1852. It is interesting to note that in New York the railroads had grown up in spite of the opposition of the canals, for until 1851 canal tolls were levied on all freight carried from Albany to Lake

Erie by the railroad. It was many times seriously proposed to restrict railroads to carrying passengers and prohibit them from carrying freight.

The Camden and Amboy, connecting Philadelphia with New York, was completed in 1837. It was this road that imported the English locomotive from which Baldwin secured his data for the construction of "Old Ironsides."

By 1841 there was a through line from Boston to Albany, which, completed in 1842, was the first through road not operated simply for local traffic. By this time the roads of New England began to assume something like system. By the end of 1848 Boston and New York were connected by the New York and New Haven, and there had been constructed 5996 miles of railroad in the United States.

The Pennsylvania railroad, chartered in 1846 and begun in 1847, was open for business in 1854, and by 1858 had completed a line to Chicago. At the end of 1860 there were over 30,000 miles of railroad in the United States, where a generation before the locomotive was known only as a curiosity.

The following table shows the date of opening of any section of a steam railroad in each state : —

Pennsylvania, Maryland, South Carolina, 1830
New York, Virginia, Louisiana, 1831
Delaware, New Jersey, 1832
North Carolina, 1833
Alabama, 1834
District of Columbia, Kentucky, Massachusetts, 1835
Florida, Maine, Michigan, West Virginia, 1836
Georgia, Rhode Island, 1837
New Hampshire, Ohio, 1838
Connecticut, Illinois, 1839
Mississippi, 1841
Indiana, 1842
Vermont, 1848
Tennessee, Wisconsin, 1851
Missouri, 1852
Texas, 1854
Iowa, 1855
California, 1856
Arkansas, 1857
Minnesota, Washington, 1862
Kansas, Nebraska, 1864
Nevada, 1868
Montana, Utah, 1869
Colorado, Indian Territory, Oregon, Wyoming, 1870
North Dakota, South Dakota, 1873
Idaho, 1874
New Mexico, 1878
Arizona, 1879
Oklahoma, 1886

Nothing can better show the rapidity with which transportation systems have developed than the simple fact that engine No. 999, the best that American skill could produce, exhibited at the World's Fair in Chicago and honored by being assigned to the Empire State Express, is now relegated to drawing local trains on a subordinate road of the New York Central.

Railroad Mileage enough to Reach the Moon. In 1899 the mileage of tracks in the United States had risen to 245,238.87, or rather more than enough to reach to the moon and constituting more than half the mileage of the world. The same year the United States employed 176,726 miles to carry mail. Not so very long ago relays of riders carrying the mail on horseback formed the connecting link across the continent. The contrast must appear startling to Buffalo Bill, who in his early manhood was one of the best known messengers of this famous "pony express."

At the close of the century the New York Central owned or controlled 10,410 miles of road; the Pennsylvania, 10,392; the Canadian Pacific Overland, 10,018; the Southern Pacific, 9632; the Atchison, Topeka and Santa Fé, 7880; the Union Pacific, 5584; the Northern Pacific, 5489; and the Great Northern, 5201. Europe had 167,439 miles. The average mileage per million inhabitants was: Sweden 1247, Switzerland 730, France 670, Denmark 669, Finland 604, Norway 571, Germany 563, England 527, Turkey 154.

The art of railroad building grew so fast as to outstrip the language. A manufacturer in one state ordering parts of locomotives or cars from a manufacturer in another state, frequently found it difficult to make himself understood because the names varied in different states, so, to obviate the difficulty, a committee of car builders came together and compiled a dictionary of 560 pages with over 2000 illustrations.

Crude Methods of the Early Days. Some of the expedients

practiced on the early railroads seem very amusing. On the Philadelphia, Germantown and Norristown railroad, if the conductor wished the train to stop he climbed a ladder to the roof of the car and ran forward till he could make the engineer hear his shouts, for there were no bell ropes and the steam whistle had not been invented. Before the appearance of the headlight night trips were avoided as far as possible. Horatio Allen, on his South Carolina railroad, ran for night trips a platform car ahead of his engine, on which was a pile of sand having a fire of pine knots built upon it.

Trevithick's engine required a horse to help it up grades of more than 18 feet in a mile. In 1832 the superintendent of the Baltimore and Ohio boasted that he had an engine that could draw 17 tons at a speed of ten miles an hour up a grade of nearly 55 feet to the mile. In 1840 the Reading railroad considered drawing 221 tons from Reading to Norristown, 41 miles, in 3 hours and 41 minutes, a notable performance. The fears for the roadbed kept down the weight of the locomotives and trains, for iron rails were hard to get and expensive. Mention has been made of cast iron and strap rails. The first rolled rails were about three feet in length, but as the art of iron making progressed they became longer, heavier, and better able to bear loads. Colonel Robert L. Stevens of the Camden and Amboy road improved the crude T rail by putting a flange on the bottom, doing away with the chairs and giving a base that could be spiked or bolted to the cross-ties. But rails were expensive. The weight they would support, and their cost, limited the size of the trains and influenced freight rates.

Steel Rails. With the development of the Bessemer process steel rails became possible and they are now almost wholly used. The life of a steel rail is now, even with its greatly increased load and use, five or six times as long as the life of the wrought iron rail. The first one tested on a railroad in England lasted seventeen times as long as the

Rio Las Animas Cañon.

wrought rail. Its application has been an important factor in railroad traffic, for it has reduced the expense of construction and repair, and, more important yet, made possible longer and heavier trains. The most powerful locomotives (see Locomotives) can now haul a train of wheat a mile long. In twenty years after the adoption of steel rails the New York Central traffic increased from less than 400,000,000 tons to more than 2,000,000,000 tons, while the average rate fell from 3.09 cents per ton mile in 1866 to .76 cent in 1886. The locomotive has cheapened transportation until the skilled workman of a New England factory can pay with a single day's wages for hauling from the wheat fields of California to the Atlantic coast enough wheat to supply himself with bread for a year.

How a Railroad is Built. A new railroad being determined upon, an engineer is sent ahead to look over the ground and determine, roughly, the best course. This is called the "reconnaissance." The reconnaissance is followed by a crew for the "preliminary survey." This party consists of a chief with several aids and their assistants, each to perform a definite part of the work. The first is the front flagman with his axmen, who cut away intervening brush and trees that obstruct the vision of the transit man. The latter with his chainmen and flagmen measures the distances and takes the angles of the line. After the transit man comes the leveler with his rodmen and axmen. These take the levels that show the elevation of the road. Last is the topographer with his sketch book, who makes a sketch of the road, showing the hills, the water courses, their direction, and the general contour of all. These maps are submitted to the chief engineer, who looks them over and indicates a line which may or may not agree with the preliminary survey.

The survey parties go over the field again, stake out the new line, record the levels, run the courses, and lay out the "approximate location," which is presented to the engineer for his final approval.

In a broken country, with rivers to be crossed, hills to be climbed, and mountains to be tunneled, several surveys are frequently necessary, but across a country offering few natural obstructions the preliminary survey may be all that is required. Great skill and judgment are demanded in determining the first location, for once selected it must be adhered to or abandoned, with all the attendant cost.

The line having been located land plans are drawn and the right of way secured. Other plans, showing excavations to be made, bridges to be built, culverts or tunnels, are made carefully, specifications drawn up, and the work let either to one contractor or to many smaller ones, and the actual work of construction begins. At this stage are brought into action steam ditchers, capable of moving 4000 cubic feet of earth a day, steam shovels that will dig as much as five hundred men, rock drills operated by steam, compressed air, or electricity, hoisting engines, cranes, pile drivers, and all that modern mechanism can devise to expedite the work; for upon the completion of the railroad wait settlers and trackmen, switchmen, brakemen, conductors, engineers, telegraph operators, station agents, and others, making up the whole army employed by a great railroad system.

Some Engineering Feats. Some of the greatest feats of modern engineering were those connected with the construction of railroads. To avoid climbing the mountain, the St. Gothard tunnel, nine miles in length, was driven through the very heart of the Alps. A cantilever bridge crosses the gorge of the Niagara river. A ravine at Kinzua, Pa., half a mile wide and 300 feet deep, is spanned by a viaduct 305 feet high and 2400 feet long, and the elevated railroads of great cities are nothing more or less than long viaducts. The demands on the constructors are in keeping with the magnitude of the work. A surveyor is expected to be able to swing by a rope

over a precipice 1000 feet in height and retain his senses and nerves. He must be "gifted with the strength of a drayman and the accuracy of a college professor."

"No heights seem too great, no valleys too deep, no cañons too forbidding, no streams too wide. If commerce demands, the engineer will respond and the railroads will be built."

Railroad Management. In no other business enterprise is systematized work so necessary as in the management of a railway. Not only must the labor be divided, but such a chain of responsibility established that mistakes cannot often occur. If they do occur, the system must immediately discover and correct them, for a mistake on a railroad may mean the loss of hundreds of lives and the destruction of thousands of dollars worth of property. The arrangement of such a system is as great a problem as any presented to a general on a field of battle.

The president of a railroad has under him, and directly responsible to him, three men: the secretary and treasurer, the general manager, and the general counsel. The secretary and the counsel arrange their own staffs and conduct their business as seems best to them. The greatest responsibility rests upon the general manager. His army is divided into eight departments, and at the head of each is placed a man directly responsible to the general manager. The following are the departments with their subdivisions: —

1. Comptroller.
    - Auditor of receipts.
    - Auditor of disbursements.
    - Traveling auditor.
    - Local treasurers.
    - Local paymasters.
    - Clerk of statistics.
2. Purchasing agent.
    - Local storekeepers.

3. Superintendent of transportation.
    - Station agents.
        - Receiving clerks and laborers.
        - Loading clerks and laborers.
        - Billing clerks.
        - Discharging clerks and laborers.
        - Delivery clerks.
        - Collectors.
        - Yard master.
            - Yard engineers.
            - Switchmen.
            - Brakemen.
    - Train master.
        - Train dispatchers.
        - Operators.
        - Conductors.
        - Trainmen.
4. Division superintendents.
5. Superintendent of machinery.
    - Master mechanic.
        - Foreman of machine shop.
            - Engine runners and firemen.
            - Hostlers and cleaners
            - Mechanics.
            - Laborers.
        - Foreman of car shops.
            - Car inspectors.
            - Greasers.
            - Mechanics.
            - Laborers.
6. Superintendent of roadway.
    - Road master.
        - Supervisors of bridges.
            - Bridge foremen.
            - Watchmen.
            - Carpenter gangs.
            - Mason gangs.
        - Supervisors of road.
            - Section foremen.
            - Gangs and track walkers.
            - Wood and water tenders.
            - Floating gangs.
            - Construction trains.
7. Car accountant.
    - Lost car agents.

8. Traffic manager.
    - General passenger agent.
        - Traveling agents.
        - Local agents.
        - Rate and division clerks.
    - Claim agent.
    - General freight agent.
        - Traveling agents.
        - Local agents.
        - Rate and division clerks.

RAILROADS OF CANADA.*

The railroads of England and those of Canada well illustrate the extreme use of transportation. Those of England were built in response to the urgent demand of an old and rich country for better transportation of raw materials and finished products. Those of Canada were built because they were military necessities, or so intimately connected with the development and welfare of the country as to warrant provincial and Dominion aid to the private companies engaged in their construction. The first Canadian railway charter was granted in 1832, and was for a line sixteen miles long reaching from La Prairie, on the south bank of the St. Lawrence river opposite Montreal, to St. Johns, on the Richelieu (the outlet of Lake Champlain), at that time the terminus of the water route from the United States via Lake Champlain. The railway was to be the water route's connecting link with the St. Lawrence river. Horses were employed as motive power and locomotives not used on it until 1837.

Canada was slow to take up the construction of railroads, for its small population was settled almost exclusively along the routes of its great waterways. Some ambitious railway schemes were later projected but there was little capital in the country and no immediate promise of any considerable traffic, and as the Erie canal, only four feet deep, had proven highly successful, great things were expected of Canada's seven-foot water way from the lakes to the sea.

* From data furnished by PROF. I. G. G. KERRY of McGill University.

The second Canadian railway was a little coal road six miles long, opened in 1835, and the first engine operating on it, the "Sampson," led the procession of locomotives at the Chicago Exposition.

The Great Era of Canadian Railways. "In 1849 it became recognized that railways of great length were practically and politically necessary to the well-being of the country; and the policy of liberally subsidizing private companies for their construction was introduced and extended, with the result that the decade of 1850 and 1860 became the first great era of Canadian railroad construction." In 1859 the first passenger train on the Grand Trunk railway passed over the Victoria Bridge, and established railway communication from Sarnia at Lake Huron to Portland on the Atlantic. The enterprise had proceeded under various charters and in the face of great obstacles. In 1851 a Canadian delegate sent to England to solicit governmental aid failed "mainly, it is charged, through the activities of a powerful syndicate of English railway contractors, by whom the scheme was finally floated on the London market. Many scandals occurred during the floating and the construction of the line, and it has never been a financial success." In 1860 the Grand Trunk had in operation 2065 miles, nearly all of it within the province of Ontario. In 1900 it operated a main line from Chicago to Portland, Maine, 1138 miles in length, and the railroad with its branches aggregated 4186 miles, about three fourths of it being in Canada and one fourth in the United States. The Grand Trunk has a large capitalization, upon a part of which it has never paid even the interest.

One of the greatest engineering feats of its time was the construction of the Roebling Suspension bridge, completed in 1854, across the Niagara river. This was for the purpose of connecting the Great Western railway, running from Windsor, on the Detroit river, to the Niagara river, and connecting by means of the bridge with

the Erie and New York Central roads. This road was afterward absorbed by the Grand Trunk. Railroad construction again languished and until after the Confederation the Grand Trunk comprised about two thirds of the railroad mileage of Canada.

The Great Canadian Pacific. When what is now the Dominion of Canada was composed of separate and sometimes jealous provinces it was not to be expected that a railroad system running from one to the other could be developed by provincial aid, but the confederation of the provinces in 1867 tended to unify their interests and encouraged the construction of long lines. British Columbia entered the Confederation in 1871 upon the express condition that the Canadian Pacific railroad was to be completed within ten years. The construction of the road was commenced in 1875 and for some years occupied the most important position in Canadian politics. It was commenced as a public work but in 1880 it was transferred to a private company which carried it to its completion, although it was from the start recognized as a public necessity and in every financial difficulty the company was aided by subsidies. Since that time most Canadian railroads have been built by private companies liberally aided by subsidies from the Provincial and Dominion governments. With the exception of the Trans-Siberian railroad, the Canadian Pacific is the longest continuous line in the world, extending as it does from St. John, New Brunswick, to Vancouver, British Columbia, a distance of 3387 miles. It has an extensive system of branches throughout Ontario, Manitoba, and British Columbia, giving it in all a mileage of 6302.7. "The Canadian Pacific, due to the liberal governmental aid it has received, has the lowest capitalization per mile of any of the transcontinental lines, and may be regarded as distinctively Canadian, built for national purposes, and with the most promising part of Canada, the far west, dependent upon it for means of existence." Many prophesied its failure as a

commercial enterprise, but it is paying good dividends and it is due to its activity and encouragement to settlers that a large part of the Northwest has been developed.

The Intercolonial, connecting the maritime provinces with Quebec and Montreal, built chiefly for military purposes, has to support a long line, some of it passing through an unprofitable country, and rarely pays operating expenses. It was commenced in 1869, completed in 1876, and cost $21,000,000 for 499.5 miles.

The greatest railroad project now before the Canadian people is the construction of the McKenzie and Mann railroads, now being built, under various charters, to afford another through line from the Great Lakes to the Pacific coast. It will be known as the Canadian Northern railway. Portions of it between the Great Lakes and Winnipeg, and for some distance beyond Winnipeg, are now under way, and some of it is already open for traffic. Its general route is well north of that of the Canadian Pacific main line.

"The Canadian roads generally are built and operated on American models; the engines, cars, tracks, etc., are of American types, and owing to the exchange of traffic between all the great lines and their American connections the freight cars are being rapidly equipped with air brakes and automatic couplers."

The speed of the passenger train is not high except in special cases. The most notable trains are the Grand Trunk "International Express," from Chicago to Montreal, which from Toronto to Montreal averages 43½ miles an hour, and the Canadian Pacific and Canadian Atlantic expresses from Montreal to Ottawa, averaging from 45 to 48 miles an hour.

"Freight rates vary with classification and locality, but through freight rates are largely influenced by competition with American lines. The Grand Trunk railway's average freight rate for the first half of 1900 was .60 of a cent per ton-mile. That of the Canadian

Pacific railway for 1898 was .76 of a cent per ton-mile, its average being higher on account of the higher average rate in the West. The grain rate of the Canadian Atlantic from Depot Harbor to Coteau Landing is about .20 of a cent per ton-mile."

Up to June 30, 1898, $941,297,036 had been expended on Canadian railways, of which 20 per cent. had been obtained from government and municipal aid. The following table gives the statistics for the principal lines for year ending June 30, 1898: —

	C. P. R.	I. C. R.	G. T. R.	O. A. & P. S.	Can. South.
Passengers,	3,327,368	1,528,444	6,041,551	104,214	522,727
Tons freight,	5,493,030	1,434,596	8,773,322	366,884	3,869,602
Receipts per mile,	$143.88	$78.83	$115.05	$80.52	$116.00
Cost per train-mile,	82.95	82.36	72.15	61.77	79.29
Proportion of operating expenses to total receipts,	57.8%	105.3%	63.0%	77.0%	68.6%
Gross receipts,	$25,470,796	$3,117,669	$18,396,010	$479,954	$4,458,629

STATISTICS — CANADIAN RAILROADS.

Year ending June 30, 1899.

Mileage built,	17,358	
in operation,	17,250	
Capital — Ordinary stock,		$270,325,496
Preferred stock,		120,974,864
Bonded debt,		362,053,494
Bonuses and government loans,		202,043,813
Other sources,		9,302,117
Total,		$964,699,784
Operation — Gross earnings,		62,243,784
Working expenses,		40,706,217
Net earnings,		21,537,567
Passengers (number),		19,133,365
Receipts per passenger,		0.83⅓
Receipts per passenger train-mile,		0.93⅛
Tons of freight,		31,211,753
Receipts per ton,		1.28¼
Receipts per freight train-mile,		1.24⅛
Cost per train, mile,		0.78

The haul is not given for either passengers or freight and rates for ton-mile and passenger-mile are therefore not reducible.

Canals—	Capital expenditure,	$76,404,279
	Maintenance and operation,	15,632,242
	Total receipts (total to date),	12,079,274
Excess of expenditure for maintenance and operation over receipts for fiscal year,		264,271
	Tonnage on Welland canals,	1,140,077
	St. Lawrence canals,	1,439,134
	Chambly canals,	271,336
	Ottawa canals,	549,986

THE PANAMA RAILROAD.

One of the most picturesque and little known railroads of the world is that crossing the Isthmus of Panama. It was constructed in response to the demands for a shorter route to California than was offered by the long voyage around Cape Horn. Its Atlantic terminus is Colon, its Pacific terminus, Panama, the oldest city founded by Europeans on the American continent. The road is supposed to correspond very closely with the route of Balboa when he discovered the Pacific Ocean in 1515. It is forty-eight miles in length and runs northwesterly and southeasterly. Paradoxical as it may appear, the traveler, leaving the Atlantic steamer, journeys southeasterly on the railroad to reach the Pacific steamer, for at this point the Isthmus of Panama runs nearly east and west, and Colon, the Caribbean terminus, is west of the Pacific terminus, Panama.

This road has other peculiarities. The telegraph poles are not poles, but worn-out iron rails, and the cross ties are of a wood harder than some metals. "It is in a Spanish country, its stock is held by a French company, its charter was granted by the State of New York, it is dominated entirely by Americans, while as ordinary laborers it employs British negroes almost exclusively."

The Cost of Tropical Railroad Building. In December, 1846,

a treaty was made between New Granada (Colombia) and the United States, by which the right of transit was given to the United States, and both powers guaranteed free transit across the Isthmus "from one to the other sea." The railroad company was organized in 1850 and the road put in operation in 1855, after losses connected with engineering operation in that tropical country that are said to have cost a life for every tie laid.

The ground is deluged with rains eight months of the year, and nearly all kinds of wood quickly rot. The cross ties are of lignum vitæ and cost $1.20 apiece; they last from twelve to twenty-five years, and are thrown away not because they rot or have worn out, but because there is not room in the cross section to drive another spike, for the wood is so hard that a hole must be bored for the spike to be driven in. As the rail bends beneath the load the tie grips the spike so firmly that the head of the spike is worn or cut off; the old spike cannot be pulled out and a new one has to be driven by the side of it. To prevent washouts from the tropical rains the surface and sides of the road are covered with concrete. There are no cattle guards or fences along this road, and the ponies, using it for a pasture ground, are a general nuisance. The greatest expense in connection with the maintenance is in keeping down the weeds, for with so much heat and moisture the growth of vegetation is rank. It is said to cost from $40 to $50 a mile for one weed-cutting operation by hand. A later method that promises success is spraying with a solution of arsenic and saltpeter. It costs only about one third as much as hand labor, and the increased mortality among the ponies seems to promise efforts on the part of the owners to keep them off the track. The officers, supervisors, roadmasters, engineers, and conductors are American, as well as the terms, phrases, and methods of conducting the road.

There is no road for wheeled vehicles between Panama and Colon,

and the railroad gets all the traffic, except such as can walk or is carried on ponies' backs, but although it runs through a fertile country bananas are the only important local freight. The United States has several times landed armed forces in Panama to preserve the neutrality of the road during political disturbances characteristic of that country.

Trans-Siberian Railroad. Siberia is the largest single country in the world. It contains 4,925,000 square miles, has a population of but 8,000,000, and is able to easily support 80,000,000. Eighty-two per cent. of the population of the Russian Empire occupy but 23 per cent. of its available territory. It is as important for Russia as for the United States and Canada to open up her government lands to actual settlers. The popular conception of Siberia is a land of icebergs inhabited by criminals. Nothing could be more erroneous. A country so large that the United States might be set down within it and leave nearly 2,000,000 square miles uncovered must possess wide ranges of temperature, climate, and natural products. The Russian Empire produces nearly half as much cotton as the United States. Southern Siberia has millions of acres of fine wheat-growing land, waiting for the immigrant and some means of transporting its products to market.

The Wonders of Siberia. Siberia already produces one tenth of the world's yield of gold, and but few mines have been working and little improved machinery used. Its immense coal deposits have hardly been touched One mine alone, with six beds, is estimated to contain as much coal as all the deposits of England. *

The Trans-Siberian railroad deserves attention, for there is no railroad in the world that has the peculiar economic, political, and military significance that this possesses. The system that connects St. Petersburg, on the Gulf of Finland, with ports on the Pacific

* John C. Covert, U. S. Consul.

ocean, attracts by its very magnitude. The longest continuous line of railroad on the American continent is that of the Canadian Pacific running from Vancouver, British Columbia, to St. John, New Brunswick, a distance of 3387 miles. The railroad crossing Siberia, reaching from Cheliabinsk, the eastern terminus of the European system, to Vladivostock, on the Sea of Japan, is 4717 miles in length, and its branch, running through Manchuria, the Northeastern province of China, to Port Arthur on the Strait of Pe-chi-li, 1273 miles in length, gives with its European mileage a system 6700 miles in length before any of its feeders are built.

The Siberian railroad was first proposed by an American named Collins in 1857. The next year three Englishmen offered to furnish capital and build the road. The Czar took all these plans under consideration and filed them for future reference, for it is the government policy to employ only Russian engineers, Russian labor, and Russian capital as far as possible, and this policy has been rigidly adhered to. While the road is for the ultimate purpose of developing the natural resources of Siberia, it is its strategic value that has hurried its construction. From St. Petersburg to Moscow, a distance of 600 miles, there is scarcely a curve, and none that are needless. On the Siberian road proper there are many strips for eighty miles or more without a curve. The last rails were laid December 28, 1899, giving direct communication from Vladivostock to St. Petersburg.

No other road has such mining and manufacturing prospects. Its political and military significance are even more striking. It affords Russia through her own territory a safe passage to the Pacific coast for her troops and munitions of war. It renders futile Great Britain's command of the sea for any purpose of balking designs that Russia may have on China. It brings Pekin within two weeks of St. Petersburg and greatly augments Russian influence there.

Magnitude of the Undertaking. "The builders of the road had

to make a scientific exploration of half a continent and drain swamps and utilize peat bogs for fuel, lay out irrigation ditches, dig wells, provide for the housing, feeding, and health of incoming settlers and their animals, to erect schoolhouses, bring in agricultural papers to show the immigrant how to plant, water, and raise crops fit for the soil and climate, make country roads and bridges, arrange rural mail facilities, and a multiplicity of other things about which an American railroad man has not to think."

It is not likely that the railroad will ever be a considerable carrier of freight from the Atlantic to the Pacific. The schedule time of the North German steamers between Bremen and Shanghai is forty-six days. Their freight rates per ton to Shanghai or Port Arthur are $6.25 to $8.75; to Yokohama, $8.75. In 1898 the rate from London to Shanghai was only $5.60 per ton. This is less than the price for which the Siberian railroad can afford to carry goods 7000 miles.

The road will probably do a large passenger business. The present fare from London to Shanghai by water is from $330 to $460, varying with the accommodations, and takes from thirty-four to thirty-six days. When the railroad to Port Arthur is completed the trip can be made in sixteen days at a cost of $162.80 first class, or $102 second class. The road was built in such haste that some rails weighing only twelve pounds to the foot were used, and the whole has been so hastily constructed that it is estimated $8,000,000 or $10,000,000 will have to be expended for reconstruction. It has cost from $18,025 to $25,750 a mile, and the whole cost is estimated at $400,000,000. The company is a joint stock concern and the government owns a controlling interest. When the line to Port Arthur is finished that point will be 5819 miles from St. Petersburg, 6331 miles from Berlin, and 7060 miles from Paris. The Russians are rapidly converting Port Arthur into an impregnable base of military

The Eastern Question bids fair to be the most portentous of the twentieth century, and Russia is bending every energy to prepare herself for the crisis. The future may hold a race struggle between the Anglo-Saxon and the Slav, the greatest in all history. The population of Russia in 1855 was 64,000,000; at the close of the century, nearly 140,000,000. At her natural rate of increase 1950 will find her with 300,000,000 inhabitants, and what power will then be in a position to dictate to her?

The loss of life on the Russian railroads is something frightful. With only about one eighth the railroad mileage of the United States she had in 1896 accidents resulting in 6107 deaths, to say nothing of thousands of other persons crippled for life or less seriously injured.

The Safest Method of Travel. "On a New Jersey railroad in early days there was painted on every car door a picture of a new-made grave and a large tombstone on which appeared the following inscription: 'Sacred to the memory of the man who had stood on a platform.' What a contrast to our modern vestibuled trains, in which the platform is about as safe as any part of the car!

"In the year 1887, the number of passengers killed in train accidents in the United States was 207; the number injured, 916. The total passenger travel was equal to one passenger traveling 10,570,306,710 miles. At that average a man could travel for 194 years at the rate of 30 miles an hour before he would be 'due to be killed,' and almost 46 years before he would be liable to an accident. It would seem that if one were seeking immunity from accident he should 'take a train.' It is unquestionably safer than any other way of getting over the earth's surface except walking."

Train Operating Compared with War. "While passengers on a railroad train are running such small risk of accident, the men who make a business of running those same trains are exposed to a risk

of accident that is really appalling. The Interstate Commerce Commissioners' Report for the year ending June 30, 1899, gives the total number of railway employees in the United States for the year as 227,537. The god of travel does not exact much from occasional worshipers but from his constant devotees he requires and receives an annual sacrifice of human lives that would make any heathen god turn green with envy.

"For every 155 trainmen employed during the year under consideration, one was killed; and for every eleven who were employed, one was injured. Modern warfare is a horrible thing, but it can show no such a record as this. During the same year 63,000 troops were in the Philippines, of whom 1640 were killed and wounded, making a casualty of 2.6 per cent. The railroad figures of 2210 killed and 34,923 injured, or 14.12 per cent., makes quite a startling comparison. The total number who were killed or wounded in the British army in South Africa up to July 1, 1900, was 15,000. The total number killed and wounded in the American forces in the Philippines from the time of occupation to June 2, 1900, was 2620. The estimated losses of the Filipino troops up to the same time was 12,884. These figures are from Secretary Root's report. Adding all these we have a total of 30,504. Allowing a loss of 5000 for the Boer Army up to the same time, we have a total of 35,504. Thus it is seen that the total losses of the armies engaged in the two great wars in progress during the year did not equal the number of lives lost and persons wounded in carrying on the business of transportation for the United States for a single year." *

The most numerous accidents are those due to coupling and uncoupling cars. Several states from time to time passed laws making compulsory the use of automatic couplers, but these laws were of little value, for they were often drawn by men not familiar with

* *Army and Navy Journal.*

the requirements of railroading and the jurisdiction of the state was limited.

It is obvious that a car which may journey from Winnipeg to the city of Mexico must be fitted with such couplers that it can be used with other cars from a dozen different lines on whatever road it may make up part of a train. The simplest and most generally used car coupler was a large iron link through which were passed coupling pins. Thousands of patents have been issued for car couplers, of which but few were of enough practical value to warrant consideration. Finally a committee of the Master Car Builders' Association was appointed to study the subject and recommend a coupler. They recommended the "Janney," patented 1873. After a time the United States passed laws requiring that roads should fit out new cars with automatic couplers and providing for the gradual equipment of others with them. Progress was slow and the government extended the time limit but definitely fixed the end of the century as the period when all cars must be fitted with automatic couplers.

The block signaling system, dividing a road into sections called "blocks," their length depending upon the extent of their use, is one of the most important safety devices in railroading. In cities and switching yards the section may be only a few hundred feet long; on the main line of a road it may be several miles in length. At the end of each block stands a tall post with two movable arms, called a "semaphore," pointing toward the track.

In ordinary practice the upper one has a square end and is painted red, the lower one has a fish-tail end and is painted green. The arms are continued back past the pivot and are weighted at that end. In the weighted end a red or green glass, as the case may be, is so placed that it can cover or uncover lanterns and display signals which can be plainly seen in the dark. Each color has its special significance. The word "semaphore" signifies "a sign I bear," and

accurately describes the machine. The arms are usually moved by compressed air mechanism, the valves of which are operated by electricity. In the electrical method the rails of the track are used as conductors, and by them the system is made automatic, for at the end of each block the rails are separated by an insulation. When a car enters the "block" the electric current is short-circuited through its axles and the semaphore responds and the upper or "home" arm rises to a horizontal position, and remains up while the car is on that block. An engineer following can know at once if there is a train ahead of him on the block. On many roads it is forbidden for two trains to occupy the block at one time. Other roads have a third or "caution" signal which allows an engineer to go ahead at his own risk. When the "home" signal is raised the lower or "distant" arm is brought up. This stays up till the train has passed out of the succeeding block, so the following engineer not only knows whether the block immediately ahead of him is clear or not, but he also knows whether the next one is occupied or not. After a train has passed the two blocks, both signals drop to "safety" and the following engineer can proceed. The plan just described is the most simple. Complicated lines may require many modifications or combinations of it.

A speed of seventy-five miles an hour means moving one hundred and ten feet in a second. A moderately heavy passenger train weighs 300 tons, and such trains frequently attain a speed of seventy-five miles an hour for short distances. Few realize the enormous energy represented by a moving passenger train. When the relatively light rails and fastenings which carry this train and the many curves and inequalities of the track which it must traverse are considered the wonder grows that accidents are not more frequent. It is not due to chance that there are so few of them, for many of the brightest minds of the world are continually at work to make railroad travel safer.

Locomotive Brakes. The chief appliance upon which the safety of the train depends is its brakes; all others, to a greater or less extent, tell the engineer when to shut off steam or use the brakes. With few exceptions safety is synonymous with stopping quickly and easily at the right moment. The first brake not operated by hand power was patented by Robert Stephenson in 1833. It was a steam driver brake, simple and effective. The brake shoes were placed below center and between the driving wheels of the engine, connected by a toggle joint which made connection with an ordinary steam cylinder. When it was desired to apply the brakes, steam was admitted to the cylinder, and the toggle joint was straightened and the brake shoes forced against the wheels. Although the best of modern brakes are constructed upon this principle, Stephenson made but little use of it.

Early Brakes. Then came a class of brakes the plan of which was to raise the car off its wheels and cause it to slide along on a set of runners that were substituted for the wheels when it was desired to stop the train, but this plan did not long survive for obvious reasons. The ordinary hand power brakes were introduced. These act by winding a chain around a staff, and then multiplying the power by a compound system of levers before it is applied to the brake shoes. This has been a very useful system, but as the work can be done better and more cheaply by machine than by hand it is disappearing. Other forms of brakes were those operated by hydraulic power, and those which used the momentum of the train to wind a chain on the car axles and make the car furnish the power to stop itself. In another the chain was wound around a friction wheel which was drawn into contact with the car axle by an electro-magnet at the moment when the brakes were to be applied. This had the advantage of applying the brake at every point at the same instant and thus all bunching of the cars or straining of the coup-

lings was avoided. Improved air brakes require about two seconds to apply the brakes at the rear end of a long train, but this slight delay has not proved serious. Brakes to be most effective must be under the instant control of the person who will first see the danger and the need of applying them. That person is the engineer and he can apply the air brake almost at once to every wheel of every car of the train. The air brake is the only one with which this is possible. Of the different air brakes the Westinghouse is most generally used.

Westinghouse Air Brake. The first air brakes made their appearance about 1868, but, as usual with new appliances, were faulty. To George Westinghouse, who began his experiments in 1869 and took out his first patent in 1872, more than to any other man, is due the credit for the automatic brake that can stop an ordinary freight train within its own length and bring an express train flying sixty miles an hour quickly and easily to a standstill within less than a thousand feet.

Essential Parts. Underneath nearly every passenger coach can be seen two cylindrical tanks. These are reservoirs holding compressed air. Each reservoir connects with a cylinder having a piston at each end. The pistons are attached to levers connecting with brake shoes, or curved pieces of metal, applied to the face of the car wheels to retard their motion. A pipe, called a train pipe, for the conveyance of compressed air, runs from the engine to every car equipped with the air brake. The connections between each car are made with a flexible hose having coupling joints. The first Westinghouse brakes were of the "straight air" variety; that is, the compressed air was stored in a cylinder in the engine, and when applied through the train pipe set the brake shoes on each car. By this means the brakes could be applied by the engineer as forcibly as he chose, a desirable feature, but in case of a train breaking in two

the brakes would be useless when they were most needed. Again the urgent need brought forth the remedy, and the automatic brake with the triple valve was devised.

Modern Brake and its Operation. As now operated, compressed air is stored in the reservoir of each car by means of a steam pump located in the engine. In usual service the pressure in the reservoir of the car is about 70 pounds, and in the reservoir in the cab, about 100 pounds. Under the engineer's left hand lies a lever controlling the air brake mechanism. The brake is almost a mechanical paradox, for it supplies its force when it lets go and releases its grip when it exerts most power. If the engineer wishes to apply the brakes he moves the lever and cuts off the reservoir in the cab from the train pipe. The pipe being relieved of the 100 pounds pressure from the engine, the 70 pounds pressure in the reservoir under each car is free to act. This it does by forcing out the pistons in each cylinder, which are attached to the long levers that move the brake shoes, and the brakes are applied throughout the train. To release the brakes the engineer moves the lever and connects the reservoir in the engine with its 100 pounds pressure with the train pipe. This overbalances the pressure in the reservoir of the car, the pistons are forced back, and the brakes released. It is obvious that an accident to the train pipe which relieves it from the pressure in the engine will allow the brakes to act automatically.

The interlocking switch and signal system is so efficient that it is now in use on nearly every important railroad of the world. A railroad yard is a labyrinth of tracks and switches. If it were left to anyone to operate the switches as he had occasion to use a track, confusion would run riot and innumerable accidents occur. The combinations that can be made by even a limited number of switches are so many and so intricate as to rival a Chinese puzzle. The clearest headed man is liable to muddle if he is hurried. Fortunately,

the system can be reduced to mathematical combinations and these worked out by machinery. For example, take a main line and a branch line running from it, the junction being made by a switch (facing point) where the inside rail narrows down to a point and connects with the outside branch rail similarly narrowed. By sliding the point rails a few inches one side or the other across the track bed, the line can be changed from main to branch or *vice versa*. To prevent the switch from moving under the weight of the train and perhaps causing disaster, the switch is locked in its proper position. Before the switch can be changed from one position to another it must be unlocked, and to do this the guard rail must be raised above the level of the track. This cannot be done while the switch is held down by the weight of a train. The switches and semaphore signals are moved by sets of levers in a tower built beside the track where it will afford a good view. The signal man within the tower operates the system by means of the levers. Suppose the track to be prepared for a train to pass on the main line. The switch is first unlocked by reversing the position of a lever, which we will call lever 3 and which then allows lever 4 to turn the switch to the main line. If the signal man then tries to set the signals that the main line is clear, he finds that lever 2, which should work the "home" signal, will not move. The reason is that the switch has not been locked. So he puts lever 3 back in its normal position and thereby drops the guard rail and locks the switch. He can then move lever 2 and set the semaphore signal at "safety." The semaphore will always drop to "danger" unless held to some other position. Thus any break in the signal mechanism could only delay traffic, and not endanger the train. There is still another semaphore, perhaps half a mile down the track, which shows the engineer the condition of the switch ahead of him. It is yet hanging at danger, and at its sight the engineer would stop. Lever 1 now sets this at safety. If the

signalman had tried to move it to safety before he had set lever 2, or the home semaphore, it would not have moved. As it is, the switch is locked in position and all the signals are at safety and the train passes on the main line. Suppose another train following it is to pass on to the branch. If the signalman tries to move the switch to the branch line by lever 4, he finds it has been locked by lever 3. Lever 3 has been locked by lever 2, and that in turn by lever 1. So he places lever 1 at normal. This sets the distant semaphore at "danger" and releases lever 2, which he then returns to normal, setting the home semaphore at "danger" and unlocking lever 3. Then by pulling lever 3 back he unlocks the switch and turns it by the aid of lever 4. Then the switch is locked by lever 3, and signals 2 and 1 set in turn at "safety." The example given is the simplest possible and has only four levers. Such is the working of the interlocking switch and signal system, which makes it absolutely impossible to make an improper combination of the switches and signals. All that a drunken or careless signalman can do is to delay traffic, for the signals will invariably stop at danger till he has set the proper combination and established a clear track. What a maze must be the switch tower of the London bridge, where there are nearly 300 levers! Without the interlocking system no human mind could successfully operate so many switches and signals.

Where the tower controls a short section the switches and semaphores are operated by the direct leverage from the tower levers. In most cases the distance is so great that compressed air at each switch and signal is led into a cylinder, where it acts upon a piston. The valve which controls the air is operated by a lever in the tower. The inventive genius of Westinghouse changed the signal tower from a clumsy array of great levers to a delicate instrument. The valves which control the switches and signals are connected with the tower by pipes filled with a liquid that will not freeze. Compressed air is

elastic, and there is lost motion and lost time. The liquid transmits the impulse instantaneously to the chamber filled with compressed air. In the old style all the work was done by the signalman's strong right arm, if that was powerful enough, and it sometimes was not. The levers of the new system can be moved by a finger's weight, providing they are moved in the proper order. But the interlocking is just as perfect, and it is impossible to move a lever at the wrong time. Mr. Westinghouse has further placed in front of the signalman's eyes a model on which every switch and signal under his control is plainly shown. By means of an electric device, the movement of any switch or signal is immediately reproduced on the model. By its help the signalman, without even looking out of the window, can tell whether his switches and signals are working all right.

On many railroads an additional safeguard is employed to prevent an engineer from running past a danger signal. Sometimes the weather is foggy and sometimes the engineer relaxes his vigilance for an instant. Either may mean a wreck. So there is placed beside the track at each signal a machine which slides a torpedo out on the rail when the line is not clear. If the engineer runs past the danger signal the torpedo explodes and its noise warns him. But his danger isn't over when he has obeyed the torpedo. If he cannot give a good reason why he ran past the danger signal, he is suspended for the first offense and discharged for the second. Such discipline has a tendency to inculcate a deeply rooted respect for danger signals. The precautions taken at railroad crossings are familiar to all. Grade crossings are gradually becoming obsolete. In the cities they make the operation of the railroad more expensive, for they require the attendance of a signalman, force the trains to run slower, and delay traffic.

The closed vestibule, which allows safe passage from one car to

another, may be called a safety device. It has practical efficiency in other ways, for it strengthens the car and reduces air resistance. Two or more tracks, on each of which all the trains are moving in one direction, also conduces to simplicity of operation, and so to less expense, increased traffic, and added safety.

Steam heating and electric lighting have banished the old-time stove and the oil lamp, and with them disappeared the horror of the burning wreck.

TUNNELS.

The longest tunnel in the world affording passage for a railroad is that of St. Gothard, which pierces the heart of the Alps. It is nine and one quarter miles in length, twenty-six feet wide, and twenty-one and one half feet high. It cost $11,175,000, or about $229 per foot in length, consumed nine years of continuous labor in building, and is one of the greatest feats of engineering of any age. The tunnel under the pass was begun in 1872, and in 1881 the first locomotive passed through.

ST. GOTHARD TUNNEL.

Wonders of the St. Gothard. The approaches to the tunnel are more wonderful than the tunnel proper. Between Erstfeld and Biasca there are fifty-six miles of railroad, nineteen miles of which is tunnel. This distance is divided between twenty-one tunnels on the Swiss side and twelve on the Italian side. The mountains are so steep that to get the trains up to the tunnel level a most novel method was resorted to. Four of the approach tunnels on each side are in the form of spirals, for when it became impossible to proceed on the upward path by building the road in a groove cut out of the face of the cliff, the engineers plunged into the face of the mountain and made a tunnel which described a complete circle within the heart of the mountain and emerged high above the

point where it entered. There are four such loops on each side of the pass before the level of the great tunnel is reached. During the course of its construction 4000 men were constantly employed. Improvements in rock drills and compressed air machinery lightened their labors and enabled them to progress at a speed never before reached in tunnel construction. Ventilation was improved by carrying the air into the tunnel in great pipes and liberating it near where the men were at work. When it is understood that without some such plan there is no circulation of air in a tunnel, and that the temperature is frequently far above 100 degrees Fahrenheit in the deeper tunnels, it can be seen what a boon this was to the men. Dynamite was perfected and superseded gunpowder as a blasting agent, and the rate at which the tunnel could be built increased from month to month as the newer inventions were made and came into use. Work was begun at each end, and when the two ends met in the heart of the mountain only thirteen inches difference was found in the direction of the approach and only two inches in the level, a remarkable tribute to engineering skill.

ON THE ST. GOTHARD RAILWAY.

The St. Gothard tunnel is wholly within Swiss territory, but the project was considered so important and of so much advantage to Northern Italy and southern and southwestern Germany that in 1869 a treaty was concluded between Italy, Germany, and Switzerland by which they agreed to become partners in its construction. Italy contributed 45,000,000 francs, the others 20,000,000 francs each. The chief difficulty was the large quantity of water encountered, but such improvement had been made in machinery that although the St. Gothard tunnel was begun only a year after the Mt. Cenis

tunnel was completed, progress was made at the rate of 14.6 feet per day for the former to 8 feet per day for the latter.

Tunneling under Simplon Pass. Monsieur Brandt of the St. Gothard tunnel signed a contract with the Jura-Simplon Railroad Company for the construction of two tunnels under the Simplon pass, and guaranteed the completion of the main tunnel within five and one half years. The tunnel must be completed by May 13, 1904. If not, the contractors are liable to a fine of $1000 a day. If completed before that date they are to receive a premium of $1000 a day. At the close of 1899, 9653 feet of tunnel had been made. A series of ten holes is bored in the face of the tunnel and a blast put in and exploded. "Strange to say, no sound of the explosion is heard a thousand yards away from the working point, and yet the air pressure at that distance is such as to cause pain in the ears." At the instant the charge is exploded in the bore holes a huge air gun 300 feet long, with a caliber of six and one half inches, charged with compressed air at 1500 pounds pressure, dashes 900 gallons of water against the falling rock and washes it away from the face of the tunnel.

When completed, this tunnel, connecting the valley of the Upper Rhone in Switzerland with that of the Diveria in Italy, will be about twelve and one fourth miles in length and the longest railroad tunnel in the world. Instead of one tunnel there will be two small ones about fifty-eight feet apart running in parallel lines. The plans have been carefully studied, new machinery and new methods introduced and the work is progressing satisfactorily.

The Mont Cenis Tunnel was constructed to afford railway communication between France and Italy. It was begun in 1857, and opened for traffic in 1871. It is seven and one half miles long and extends for the most of the way through solid rock. The tunnel was begun by hand drills, but rock drills operated by compressed air created a new epoch in mining operations and made it possible to

progress three times as fast. As completed the tunnel is wide enough for a double track railroad.

The Arlberg Tunnel, piercing a branch of the Alps in Tyrol, a province of Austria-Hungary, was begun in 1880, opened in 1884, is six and one half miles in length and occupied three years and nine months in construction. Improvements in tunneling machinery enabled the work to go forward at the rate of 27.8 feet per day. About 1,760,000 pounds of dynamite were employed for blasting purposes. The contractor finished the tunnel 420 days ahead of his time limit, thereby winning a bounty of about $168,000. The tunnel cost about $154 per foot.

The first railroad tunnel in America was the Alleghany Portage, running through a spur in the Alleghany mountains. It was 901 feet long; was begun in 1831 and completed in 1833.

The longest railroad tunnel in America is the Hoosac, on the line of the Fitchburg railroad, passing through the Hoosac mountains in the western part of Massachusetts. It was begun in 1854, although for some years but slow progress was made, due to financial difficulties and the lack of machinery. The Hoosac tunnel passes under two mountains with a valley between. The bottom of the valley is about 1000 feet above the top of the tunnel, and in this valley a shaft was sunk to the proposed depth and work begun in both directions, four stretches of tunnel being in progress at once. Its total cost was about $11,000,000.

The Cascade tunnel, on the Northern Pacific railway, begun in 1886, was completed in twenty-two months at a cost of $118 per foot. The tunnel is 9850 feet long and 16½ feet by 22 feet in section. The machinery, fuel, and supplies were hauled over 100 miles, to a height of 3970 feet, on roads made by the contractor through hitherto untraveled country. Bridges were built, streams dammed to give the necessary water power, and the whole built in the midst of a wilderness.

The tunnel for the Great Western railway of England, under the Severn, is four and one half miles in length and was commenced in 1873. An almost uncontrollable inpouring of water was encountered, twice causing the work to be suspended, but the tunnel was finally completed and the first train passed through in 1886.

The Mersey tunnel, connecting Liverpool and Birkenhead, was begun in 1881 and completed in 1886. St. Gothard was a triumph of surveying, but the Mersey tunnel was a marvel. It is 23,615 feet in length, and, when the two ends met under the river, their lateral deviation was less than one inch, and the difference in level was just 1-100 of a foot.

At Sarnia, Ontario, there is a tunnel 6050 feet in length under the St. Clair river through which the Grand Trunk trains dash in a trifle over one minute.

Constructing a tunnel in solid rock means simply the blasting of a passage through it, but when the passage extends through such materials as clay, silt, gravel, sand, or any strata bearing water, means must be taken to prevent caving in before the passageway can be arched and protected. In the construction of the St. Gothard tunnel, the arches lining it were twice crushed and were finally made of cut granite blocks, five feet thick at the top and ten feet at the sides.

In 1825, Brunell, the famous British engineer, began the construction of a tunnel under the Thames, near the site of Trevithick's attempt, two miles below London Bridge. Soon the inpouring mud and sand proved too much for the existing methods of engineering. Brunell then devised a shield protecting the whole face of the tunnel and containing the rude germ which Beach of New York and Greathead of England have improved upon and made the tunneling shield of to-day.

The Greathead Tunnel Shield. In 1869 the Tower subway

under the Thames was lined with cast-iron plates. These have since come into pretty general use for tunnels and subways. In 1889 Mr. J. H. Greathead completed a tunnel under the Thames for the South London railway, and the improvements he made in the shield and the methods he employed are now widely used wherever the strata to be penetrated are of the same character. Instead of lining his tunnel with brickwork, or cut stone, he employed huge cast-iron rings, and surrounded them with a layer of concrete. Where the conditions and the magnitude of the operation warrant the expense of the Greathead system it is carried on about as follows: Starting on the site where a future station is to be located, a shaft is sunk to the level of the proposed tunnel, and solidly walled with brick and cement. Then the tunnel is started from the shaft in opposite directions. As soon as work is enough advanced to make room for it, the "shield" is introduced. The shield is a great tube of steel of the shape of the finished tunnel, and a little greater in its diameter than the diameter of the cast-iron rings with which the tunnel is to be lined. It is open at both ends, and the front end has its edges sharpened to a cutting edge. It is long enough to afford room for two or three of the rings twenty inches wide, and the diggers or "muckers" who work at the face of the tunnel. As the tunnel is not circular, but slightly oval, the rings can be carried through the completed portion of the tunnel by turning them so their smallest diameter will coincide with the greatest diameter of the tunnel. Brought to the right place and given a quarter turn, they fit exactly into their final position. Inside the shield are eight projections. Against them rest the heads of eight hydraulic presses, whose bases butt against the flange of the last ring. Pressure applied by these presses forces the shield forward the length of one ring, or twenty inches. The diggers remove the earth thus cut loose. Another ring is passed forward and put in place. Thus the work goes on,

without danger of a cave-in. Each ring has a flange three inches wide pointing inward. A tarred rope is placed between them and the flanges bolted together, making a tight joint. At the top, bottom, and sides of each ring are small holes. Grout, made of Roman cement, is forced, under a pressure of thirty pounds to the square inch, through the bottom hole until it appears at the side holes. It is then forced through the top hole till no more can enter. Thus the space outside the rings is filled with what becomes as hard as stone. The cement protects the rings and prevents water from entering. It also stiffens the rings, and does away with vibration and much noise that at first rendered subways objectionable. Only 20 inches are exposed without a rigid support, and this only while the shield is forced ahead one ring length, the ring placed in position and the grout introduced. Greathead's tunnel passed under the pier of the Southwestern railway's Thames Bridge. The directors tried to stop the tunnel for fear it would injure the foundation of the bridge. When they made their demand they learned, much to their surprise, that the tunnel had passed their foundation and a half a mile beyond. They withdrew their objection.

If water, quicksand, or mud is encountered, and danger is anticipated, doors are built in the rear of the shield through which the workmen can escape in an emergency, and close the doors behind them. Partitions are built in the tunnel back of the shield and compressed air pumped in. This helps to hold the water back and prevents caving. The cutting end of the shield is sometimes partly closed to prevent the ingress of earth faster than it can be handled.

When conditions are such as to require the use of compressed air some method is necessary to remove the earth without decreasing the pressure. Sometimes there is a second compressed air chamber, back of the forward one, into which the dust is first thrown and from there shoveled to the tunnel proper.

A tunnel passing beneath the Thames came so close to the water that it was feared the air pressure within would burst through the thin layer of earth and the tunnel be flooded. To overcome this, clay was dumped into the bed of the river over the course of the tunnel. This gave sufficient weight to resist the air pressure, helped to keep out the water, and was afterward dredged out when the tunnel was completed.

Sometimes in city work, tunnels pass near foundations of buildings or under streets and the shield method would be too expensive to use. Steel plates ("needles") tongued and grooved like matched boards are used. These are forced ahead in the direction of the tunnel and the earth underneath removed for a portion of their length. The iron lining of the tunnel is placed in position behind the "needles" and the space filled with concrete. As fast as required the needles are forced ahead by jackscrews or hydraulic presses, exerting a force of perhaps 3000 pounds; quite sufficient to drive out of the way any small-sized bowlder they might encounter. This method is cheaper than using a shield.

Rapid Transit.

One solution of the crowded tenement house problem is to enable people to live where there is more room and to go to and from their work quickly and cheaply. When the street car companies proposed an electric conduit system in Boston, a committee of eminent citizens opposed more rapid transit facilities. They argued it was better and healthier to walk than to ride. The person whose time is money does not take that view of rapid transit. "Rapid transit" is of recent origin. The lack of it in early cities kept shops small, and each shopkeeper lived in his shop. Those engaged in manufacturing lived in their small factories. These, from the nature of the conditions, were small and always worked at a

great waste. The co-operative plan was not possible owing to the restricted transportation facilities both for men and for goods. Such conditions render a large city almost unendurable. In early times people recognized this and walled their cities with the double purpose of protection and of limiting their further growth. The literature of the Middle Ages constantly laments the tendency of mankind to crowd into cities. Sir Christopher Wren, the famous architect, in making a new plan for London after its great fire, proposed to check its growth by arranging the graveyards in a ring around the city. It was urged in Parliament that a new bridge across the Thames would cause so many people to come to London that they could not be fed.

In a modern city a different problem presents itself. In one part is found the financial center; in another the manufacturing industries are centered; in a third are located the wholesale houses, while in a fourth are grouped the retail stores; last of all are the residences of the people daily employed in these various parts of the city. If the people had to walk to and from their places of employment as in former times, they would do nothing but walk, for the modern city covers an area never dreamed of two centuries ago. The life of a great city depends upon its rapid transit facilities. Cabs and omnibuses answer for a time; horse cars double the available area of a city; cable and electric cars a little more than quadruple it. Still the cry is for ampler and swifter means of transportation. This is the problem the engineers of to-day are facing. The traffic on the street railroads of large cities is enormous, and the better the facilities the more strenuous are the demands for improvement.

Growth of Rapid Transit. Prior to 1830 nearly all the business of New York city was transacted below Canal street and nearly all the residences were below 14th street. In 1831 John Stephenson put in operation the first street car drawn by horses. "A track of

plate iron bars spiked to timbers resting on stone blocks was laid on the Bowery and Fourth avenue, on Prince street to the Harlem river." The project was not a success and was abandoned to be resumed in 1845. Horse car lines appeared in Boston in 1856, in Philadelphia in 1857, in New Orleans in 1861. A line was constructed in France in 1851, and it was not until 1870 that they were allowed in London. The horse car extended the area of New York northward, while the ferry boats built up Brooklyn and Jersey City. Surface lines were followed in 1878 by elevated lines operated by steam, but they were inadequate to meet the demands and more were built, until every available street was utilized. In 1900 electricity as a motive power was substituted for steam on the elevated railroads of New York. Now there is in progress a monster subway, and in a few years even this will probably be insufficient.

PHILADELPHIA, GERMANTOWN, AND NORRISTOWN RAIL-ROAD.

LOCOMOTIVE ENGINE.

NOTICE.—The Locomotive Engine, (built by M. W. Baldwin, of this city,) will depart DAILY, when the weather is fair, with a TRAIN OF PASSENGER CARS, commencing on Monday the 25th inst., at the following hours, viz:—

FROM PHILADELPHIA.	FROM GERMANTOWN.
At 11 o'clock, A. M.	At 12 o'clock, M.
" 1 o'clock, P. M.	" 2 o'clock, P. M.
" 3 o'clock, P. M.	" 4 o'clock, P. M.

The Cars drawn by horses, will also depart as usual, from Philadelphia at 9 o'clock, A. M., and from Germantown at 10 o'clock, A. M., and at the above mentioned hours when the weather is not fair.

The points of starting, are from the Depot, at the corner of Green and Ninth street, Philadelphia; and from the Main street, near the centre of Germantown. Whole Cars can be taken. Tickets, 25 cents.

NOV 24-3t

FIRST RAILROAD ADVERTISEMENT IN AMERICA.
TIME-TABLE OF THE PHILADELPHIA, GERMANTOWN AND NORRISTOWN RAILROAD IN 1832.

Cable Roads. In 1873 Andrew Halidie built in San Francisco the first "cable road." Power was furnished by a stationary steam engine revolving a band wheel around which was passed a long endless wire cable. The cable was carried on pulleys in a channel (conduit) underneath the roadbed. The conduit was covered by iron

plates separated by a narrow slot running the length of the street. Flat bars passed down from the cars through the slot to the cable and they were enabled to grasp or release by means of "grips." The cable being set in motion and the grip applied the car was dragged along. When the grips were released the car could be easily stopped by an ordinary brake. The cable system was used in Chicago in 1881, on the Brooklyn bridge in 1883, in London in 1884.

American vs. European System. By the American system a man can ride from the crowded part of the city to his home in the suburbs for five cents. In European cities the charge is made in proportion to the number of miles traveled, and the same trip would cost more than twice as much. The cost becomes so great for the laborer as to make his living in the suburbs an impossibility.

In Berlin in 1885 there were but 2820 private houses. Of the population of 1,122,000, 900,000 lived in tenements; 478,000 of these lived in houses of one room that could be heated; 302,000 in houses of two rooms; and 101,000 in cellar and underground tenements. The wages earned were not enough to enable them to live at more than a walking distance from their places of employment. This condition of affairs is well contrasted with Somerville, a suburb of Boston. In this city there are about 7000 houses and the population averages only about 5.9 persons per house, or about the same as in well settled country districts. These people live in a comfortable town only five miles, or one half hour's time, from their work in Boston. The necessary trip costs only ten cents per day. All the benefits of a healthful home, and the comforts of a suburban residence, are made possible to every wage earner, and the cost is actually less than would be his share of the municipal burden if he were to live in the center of the great city.

Political Significance. All this has been made possible for him

by, as Emerson has it, "paving the roads with iron bars." "The dangers to our republican form of government arise largely from the overcrowding of people in the great cities, reducing the minimum of intelligence, making slaves of the wage earners, and rendering easy the control of votes for corrupt purposes. With the scattering of industries under the highest development of rapid transit, the conditions prevailing in the great cities may be so modified as to rapidly advance the higher ideals of government. The necessity for the concentration of people behind fortified walls gave to Europe its feudal system." *

Electric Railways.

As might be expected, there are many claimants for the honor of first applying electrical energy for traction purposes. Thomas Davenport of Brandon, Vt., in 1835 made a model electric car and exhibited it on a circular track. Davenport's model carried the battery that supplied the electrical energy for use in its electric motor.

Retired from Business.

In 1839 Robert Davidson, a Scotchman, moved a railway car sixteen feet long, weighing six tons, at the rate of four miles an hour. In 1851 Professor Page of the Smithsonian Institution exhibited an electric locomotive and drew a light train on the Baltimore and Washington railway at the rate of nineteen miles an hour. All these motors derived their power from voltaic batteries, which were expensive. However, the possibility was proved and the principle awaited the cheapening of electric power.

It came with the invention of the dynamo, and the steam engine, the dynamo and the electric motor formed a magic circle. The steam

* John Brisben Walker.

engine develops the mechanical power, which the dynamo takes and turns into electrical energy; the electric motor takes the energy furnished by the dynamo and turns it back into mechanical power. A dynamo cannot create energy; it can only change the form of that furnished it by the steam engine.

Accidental Discovery. It has been said that the electric motor owes much to an accident. At the Vienna Exposition in 1873 a workman was making the connection for some Gramme dynamos. By mistake he connected one to a dynamo in operation. To his great surprise the dynamo he connected began to revolve in the opposite direction and the discovery was made that the motor and the dynamo were practically identical in structure. From that time numerous experiments were made in Europe and America by the ablest inventors of the times.

First American Line. Siemens and Halske of Berlin are usually credited with having produced in 1881 the first financially successful electric street railway. In 1888 a complete electric road was operated in Richmond, Va. The new method gave such good service that according to Mulhall there were in the United States and Canada in 1890 about 645 miles of street railway operated by electricity. At the close of the century it was estimated that there were nearly 20,000 miles, employing 200,000 men.

Electricity has the following advantages as a motive power for rapid transit: —

Power can be produced cheaper at a stationary plant than in a locomotive. Mechanically stoked boilers can dispense with the firemen and burn, economically, slack coal unfit for use in a locomotive furnace. The best stationary plants can produce a horse-power-hour on about a pound of good coal. Large compound condensing engines can produce power without increasing the waste proportionately. With the relatively smaller force of firemen and engineers in the stationary plant the cost is less for labor.

The repair bill of a stationary plant is less than for locomotives subject to all the accidents and rough usage of the road.

The "adhesion" of wheel to rail is much greater in the electrically driven car system, because the weight of the whole train is distributed over the axles to which the power is applied, and they do not turn as "dead" wheels, as they do in an ordinary railroad train. The current connecting wheel and rail seems also to increase the adhesion.

The power can be applied to all the wheels, and the adhesion of all the wheels can be used to apply propulsive power.

With the electric system there is absolute freedom from smoke and cinders.

All the parts of the electric motor move continuously in one direction. This is the ideal condition in all machines. The reciprocating parts of a locomotive must at every stroke be brought to a dead standstill and then started in the opposite direction.

The storage battery, which stores up surplus power when it is not needed and gives it out when it is needed, has greatly cheapened the cost of operating electric railways.

Patronized by Hundreds of Millions. It is estimated that in New York city there is a daily passenger fare equal to 1,643,000 persons, or a yearly movement of about 600,000,000, and over one half of these come and go from the comparatively small area below Canal street.

In 1898 the total passenger movement in the city of Paris was 288,582,000, and in 1889, the year of the previous Exposition, it was 340,000,000. In 1890 the passenger movement in London was estimated at 988,000,000.

For the last fifty years one of the greatest problems of a city has been how to carry its people to and from their work with the least loss of time. Well might Mr. Whitney, in an address to the

Massachusetts legislature, say, "While you are legislating under this roof to reduce the hours of labor, the West End Railway Co., by simply changing its system to a more rapid one, has reduced the hours of labor nearly half an hour per day."

All the available streets having been covered with surface lines and elevated roads, and the flying machine not yet perfected, the insistent demands for rapid transit forced the engineer to emulate the mole. By going underground he could use space not available for other purposes and propel his trains at a higher speed than would be safe in streets used in common with vehicles and pedestrians. The plan has succeeded, but no small amount of missionary work was necessary to remove the prejudices of property owners beneath whose feet the tunnels passed and to allay the fears of timid travelers.

SUBWAYS.

The subway has been called in to supplement the transportation facilities of a city where there are already in active operation all the lines for which there is room on its surface. Subways and tunnels, although synonymous in the popular mind, are not, strictly speaking, the same, for the subway is usually a ditch before it is a tunnel.

London set the fashion for underground railroads by opening in 1863 one three miles in length. Since then others have been built and units constructed independently have been connected until there is now quite an extensive underground rapid transit system. In 1900 there was opened for traffic the Central London railway, the third of its kind, six and one half miles long, running from the Bank of London, the center of London's commercial activity, to Shepherd's Bush, west. The clay soil through which it passed was favorable for the operation of the Greathead Shield, and as the tunnel ran under the streets of the city, nothing was paid to private property owners for right of way. The road cost about $2,500,000 per mile,

which is cheap for roads of that character. It is equipped with 8-wheel electric locomotives, thirty feet in length and each weighing about forty-eight tons. The road is operated with electricity as a motive power, taking it from a third rail. It was intended to equip the road with British locomotives, but no British manufacturer, owing to trade union restrictions making it difficult to employ workmen on extra time, would guarantee the delivery of the locomotives within the time necessary, so the order went to the General Electric Company at Schenectady, N. Y. Each train with its locomotive will weigh about one hundred and fifty tons. The cars are of the American plan, with a corridor extending down the center, and will seat three hundred and thirty-six passengers. The power is furnished by sixteen Babcock and Wilcox water tube boilers having a combined heating surface of nearly an acre and a half. The stations on this road are all at the tops of grades (slight hills). This feature possesses two advantages: the up grade assists in bringing the train to a stop at a station; the down grade makes it easier to start.

Boston's subway. Boston has a system which employs a subway in the congested portion of the city and an elevated road in the less crowded parts. In the side walls of the Boston subway are vertical steel pillars. The pillars are connected by arches made of concrete. The arches stand on end (have their axes vertical) with their convex sides facing outward. The vertical arches along the sides give the side walls a peculiar scalloped or corrugated appearance, but it was constructed in that manner to enable the walls to resist the side pressure due to heavy traffic and the weight of buildings. The roof is of steel beams connected by arches of concrete or brick.

New York's Subways. New York city will have, when it is completed, the most complete and fully equipped underground system of any yet devised. As now planned it will run from the City Hall park nearly north to Forty-second street, westward on Forty-second

street to Sixth avenue, under it and Broadway for a considerable distance to 104th street, where it branches, one branch continuing north and the other northeast to the Bronx river. The branches will be large enough for a double track road; the main line for four tracks. Two tracks of the system will be reserved for express trains, which will be run at a high speed and make few stops. In the vicinity of the City Hall the subway will carry its tracks in two stories; two tracks above and two below. It is expected that the express trains will make a trip from City Hall to the Harlem in not far from fifteen minutes. The whole contract was awarded to John B. McDonald for $35,000,000, probably the largest contract that a single individual ever undertook. The ground was formally broken in front of the City Hall, March 21, 1900, Mayor Van Wyck turning the first spadeful of earth. Actual work was commenced on May 14, 1900. It is expected the subway will be completed within three or four years from the time of its inception. The natural conditions are rather favorable. The greater part of it will be constructed by the "cut and cover method," tunneling being necessary only for a comparatively short distance and then through rock, where the use of a shield will not be required. The east branch will be about four hundred feet in length where it passes under the Harlem river, and caissons can there be used at less expense than a shield. It is now planned to extend the tunnel from City Hall park to Bowling Green, thence under the East river to Brooklyn City Hall. In passing under the river the tracks will be carried in two cast iron tubes each fifteen feet in diameter and affording room for one line of track. The contemplated extension is four and one half miles, and one and one half miles of it would be of cast iron tubing. The New York subway will consist of a steel and concrete water tight conduit. The following is the general method of construction:—

Method of Construction. As the great ditch is dug the bottom is covered with a layer of concrete. Over this a layer of hot asphalt is poured and smoothed down; on the asphalt is laid a sheet of felt, then another layer of asphalt, and the process repeated as often as the character of the ground may seem to render it necessary to keep out moisture. The waterproofing is covered with another layer of concrete in which are set the bases for the tracks and the pedestals for the steel columns intended to complete the sides and carry the weight of the roof. The sides and roof are given the concrete and waterproof coating as well and the whole subway made water tight. When completed it will be superior to all others, in capacity, ventilation, lighting, and efficiency.

The rolling platform at the Paris Exposition proved popular. It consisted of three parallel paths: the first a stationary one 3.5 feet wide; the second or middle one 3 feet wide, moving at the rate of 2.6 miles an hour; the third path, 6.5 feet wide, and moving in the same direction as the second at the rate of 5.25 miles an hour. The system, 3400 yards long, was driven by a number of electric motors at fixed points in its course. To the shafts at these motors were fixed two pulleys of different sizes. The large pulley helped move the high speed platform, and the smaller pulley the low speed platform. The platform was divided into short lengths, so joined that it would round curves easily and leave no dangerous gaps. Passengers were carried to the stationary way by means of ramps. On such a system the middle platform moves so slowly that one can step upon it from the stationary platform and be carried along by it as fast as a moderate walk. Then the difference between the low speed and the high speed platforms is so little a man can step from the low speed to the high speed platform and find himself moving at the rate of 5.25 miles an hour. He can add to the motion of the platform his own speed by walking in the direction in which the plat-

form is moving. If he wishes more time to look at anything along the way, he can walk in the opposite direction, step upon the middle platform, or even step off upon the stationary one at any point.

Moving Platforms vs. Elevators. The Paris moving platform was twenty feet above the street level, and to bring the passengers up to it the company employed broad, thick, strong, endless belts (ramps), each running over two large pulleys so set that the belt, at a gentle incline, moved continuously, its upper surface carrying up anything placed upon it. The belt was stiffened and run on numerous rollers. Standing upon it one had no feeling of insecurity. It was given a vertical speed of one foot per second. Anyone wishing to go faster could do so by simply walking in the direction in which the ramp moved. In competition with a modern elevator of the best type, the two working continuously, the ramp lifted 4000 people twenty feet in one hour, as against 400 for the elevator. There has been installed on the Third Avenue elevated railroad of New York city a ramp able to lift 3000 passengers an hour from the street to the level of the platform. The receipts at the ticket office where it is in use show that the device is popular with the public.

Rapid Transit by Means of Moving Platforms. A system of moving platforms has often been urged for rapid transit in great cities. By increasing the platforms any desired speed could be attained. Passengers could travel slowly by remaining on one of the intermediate platforms. There would not be the trouble of stopping and starting, for the passengers could board the platforms and leave them at any time or any place. A street car stopping for a passenger usually loses from five to ten seconds of time. There is a further loss of energy, employed to stop and start the car. The aggregate loss of time and energy in a city where there are 600,000,000 fares collected in a year assumes no small proportions.

Wheeled Vehicles.

The first wheeled vehicles probably resembled the rude bullock carts now in use in India. These consist of two solid wheels made by cutting off the end of a log, a hole made through the heart, a box-like body with a solid beam crossing it underneath, the ends of the beam rounded and thrust through the holes in the blocks. The wheels are kept in place by a pin through each end of the beam. A rude pole is attached, to which are fastened the cattle. Such vehicles, which go crawling across the plains of India or Southern Africa, their ungreased axles sending out shrieks of protest that can be heard for a thousand yards, are a fair type of man's first carriage. The Egyptians and Assyrians made considerable advance in the building of chariots, gradually developing the wheel until it consisted of a hub, spokes, felloes, and a bronze tire. The box-like body and solid axle were retained and nothing was known of springs. The war chariots had huge bronze scythes attached to their axles, and when driven at high speed through a mass of men created dire havoc. They could be operated only on smooth ground.

At the beginning of the Christian era the carriage had acquired two more wheels and had come to represent a mark of rank or wealth. Its lack of springs and the extreme discomfort attendant upon riding in it over an uneven surface probably had some influence in inducing the Romans to build smooth as well as durable roads. With the decline of Rome and the advent of the Dark Ages the roads fell into such a horrible condition that wheeled vehicles practically disappeared. All the carrying trade of Europe was conducted by means of horses, asses, and mules, bearing pack saddles. As late as 1550 there were only three rude coaches in Paris. The coach of state was introduced into England in 1555 for Queen Elizabeth. It was a strong, clumsy, four-wheeled vehicle without springs of any

kind, and a modern ice-wagon with a little decoration would appear like a palace car beside it. At the beginning of the eighteenth century heavy lumbering wagons drawn by eight, ten, or twelve horses, carried the freight from city to city. At the rear end of each wagon was a small space covered with straw, into which half a dozen passengers could be crowded, sitting upon the straw, for want of other seats. In 1750 the first line of stagecoaches was established between London and Birmingham, and in good weather they were able to make the trip of 116 miles in three days and three nights. An expert bicycle rider can now easily make the same distance from sun to sun.

In 1754 the first stagecoach line was established between London and Edinburgh and it was advertised that "a two-end glass coach machine hung on steel springs, exceedingly light and easy, will go through in ten days in summer and twelve in winter, the passengers lying over during the Sabbath at one of the villages on the route." The distance is about 400 miles, and the Great Northern railway now makes it in eight or ten hours.

Steel springs for coaches came into use about 1750 and with the improvements of roads due to Macadam, Telford, and other engineers, the development of the modern carriage began.

Alexander's chariot was about as comfortable as a city dump cart, and the coach of state of Cæsar could not compare for strength, comfort, efficiency, and speed with a modern brewery wagon.

First Bicycles. It is evident that good bicycles could not precede good roads. As early as 1779 the primitive ancestor of the bicycle, afterward known as the "hobby horse," was described. This machine consisted of a bar of wood with a wheel at each end in the same plane. The rider, sitting astride the bar, propelled the machine by pushing against the ground with his feet. Improved upon by Baron von Drais in 1816, it was called the "Draisine." This machine had a saddle; the front wheel was guided by a handle-

bar; rests supported the elbows, and leaning his weight upon them the operator propelled the machine by striking the tips of his toes against the ground. This was popular in the cities for a time, and in various forms was called the "Draisine," "velocipede," "dandy horse," and "celerifere," but the mode of propulsion was the same in all.

In 1840–41 a Scotch inventor named McMillan made a bicycle built of wood, having pedals and cranks, and connected the rear wheel with his cranks by "connecting rods." In 1846 Dalzell, another Scotchman, improved upon McMillan's machine and was able to travel with it as fast as the ordinary coach.

From "The Boneshaker" to Pneumatic Tires. In 1855 Ernst Michaux, a French inventor, first applied the cranks and pedals directly to the driving wheel. Michaux's invention is generally considered the germ of the modern bicycle, and France has erected a monument to his memory. Michaux was a locksmith with but little capital, and not much was done with his machine. In 1866 another Frenchman, Pierre Lallament, took out a patent in France and the United States for an improvement of Michaux's machine, and for a time was supposed to be the real inventor. From 1866 until 1870 the "boneshaker," as it came to be called, had quite a popular run. Then wheels began to be made of all iron and steel and the front wheel grew larger, producing the familiar high wheel of some years ago. To avoid "headers," which were frequent with the high wheel, the little wheel was put ahead and the rear one connected to the pedals by straps or ratchet wheels. From this the transition to the "safety" of to-day was rapid, but the one thing that more than anything else made the bicycle popular was the application of the pneumatic tire. This was invented by R. W. Thompson in 1845, but it was not designed for the bicycle. It was applied to the bicycle by Dunlop in 1889, and the weight rapidly came down from

the hundred pound machines to the light roadsters of twenty pounds or less.

The bicycle of to-day is a marvel of strength and lightness, and is responsible for many improvements in other machines. Among them are the principles of ball bearings, suspension wheels, seamless steel tubing, and the pneumatic tire. It has been one of the most potent factors in the development of good roads, for the presence in the United States and Canada of a million bicyclers who are also voters has been felt in the legislation pertaining to improved highways. In 1896 the United States Congress established a national bureau of highways for the purpose of aiding the states in the construction of scientific roads. All military powers have given considerable attention to the application of the bicycle to military use, and in nearly all armies bicycle corps are formed.

Marvelous rates of speed have been attained with it, and records are broken every day of the racing season. In 1899 Murphy, riding on a plank path between the rails of the Long Island railroad behind a train with a hood built over it to shield him from the wind, made a mile in fifty-seven and four fifths seconds, and was picked up bodily by his friends, wheel and all, and drawn on board the train while it was in motion.

Ocean cables and bicycles are rapidly using up the visible supply of rubber. As an example of the growth of the business, the Pope Manufacturing Company in 1888 employed 500 hands, and at the close of the century, 3800. It is estimated that the United States alone annually turns out $30,000,000 to $40,000,000 worth of bicycles.

The Automobile.

Without question the greatest advance in transportation within a few years is represented by the automobile, yet the welcome it met has been no exception to the general rule that improvements are

usually coolly received by the public, who are prone to say, "It will not work"; next, "It is dangerous"; finally, "Every one knew it before."

Although the development of the automobile has been so rapid that it is not even described in some of the latest encyclopedias, yet the idea is older than that of the locomotive. The steam carriage of Cugnot was operated on the road. Patents were issued to Watt for the application of steam to road carriages. Even Trevithick, the father of the locomotive, tried his first carriage on the road, and it was due to its success on rails, the wretched state of the roads, and the violent opposition of all interested in stagecoaches, inns, canals, and kindred interests, that the locomotive outstripped the automobile.

THE FIRST HORSELESS CARRIAGE.

Automobiles not New. Cugnot produced a successful model in 1763.* He was employed by the French government in 1769 to make a three wheeled steam carriage for transporting cannon. There are many stories of his adventures. One relates that one of his machines having overturned in the streets of Paris, the authorities were at a loss whether to treat him as a genius or a culprit, and with strict impartiality imprisoned him, released him, and gave him a pension. Cugnot is certainly the pioneer in steam road carriages.

In 1822 Sir Goldsworthy Gurney, a scientist of no mean abilities, constructed several steam carriages which were successfully operated about London, but met with so much opposition from rival interests as to render them unprofitable.

In 1833 a machinist named Squire, aided by a financial backer,

* See page 11.

Colonel Macerone, built several practical steam carriages, one of which is said to have drawn a carriage 1700 miles without any repairs. It was capable of making an average speed of seventeen miles an hour, and coke, which was used for fuel, cost seven cents a mile. These coaches were efficient and but for the bitter opposition of the stagecoaches and allied interests could have done a profitable business.

The automobile developed enough to be commercially practicable by the year 1857, when the British government passed a law restricting their speed to two thirds that of a stagecoach. This was followed in 1865 by a law which was designed to suppress them as a dangerous nuisance. It would not be hard to guess what motives inspired such legislation. Horse dealers, innkeepers, stage drivers, and some workmen feared the new machine would rob them of their bread and butter. The same spirit of ignorance, violence, and conservatism was responsible for the destruction of Denis Papin's first steamboat and the textile machinery in English factories. It finds its latest expression in restrictions upon the British manufacturer that render him at a disadvantage in some respects with his American competitor, and which are responsible for the American locomotives on the Midland railway of England, the filling by an American bridge company of Kitchener's hurry order for the bridge at Atbara, and the appearance of American bridges in India.

The "Auto's" Hard Struggle. The English law of 1865 provided that each machine must have three drivers with it, one of whom was to precede the carriage on foot at a distance of sixty yards, and to carry a red flag to warn all persons that the carriage was approaching. There were to be no whistles blown and no steam was to be blown off. This forced the engines to work at low pressure. Any driver of a horse could compel the drivers of the automobile to stop at any point and for any length of time by simply

raising his hand, and to disobey the signal meant a severe fine. The speed of the carriages in the country was not to exceed four miles an hour, and in the towns it was never to be higher than two miles an hour. The name and residence of the owner of the carriage were to be painted conspicuously on the carriage. The hours when it dared to venture out on the public road were to be regulated by the local authorities of each borough. As if these regulations were not stringent enough, more were added in 1878. Each automobile was taxed £10 a year in each borough in which it was operated. The first law covered only steam carriages, but this law was extended to include "a locomotive propelled by steam or by any other than animal power." The automobile was restricted to certain hours, which were seldom the same in adjacent boroughs. In Gloucestershire they were allowed to run only between the hours of 8 P.M. and 4 A.M. These absurd laws stood until 1896.

As early as 1878, in France, there were purchased at county expense several traction engines in every county and these were regularly loaned to the small farmers to transport their crops to market. It is significant that in the year 1898 there was $150,000,000 of French capital invested in the manufacture of automobiles, and this manufacture gave employment to 200,000 people. Never before was there such a demand for skilled labor as that which the revival of the automobile caused in France.

Its Final Ascendency. What the "Rainhill Contest" was to the steam locomotive, the automobile race of July 22, 1894, was to the history of the automobile. The race was arranged by *Le Petit Journal* and the course was from Paris to Rouen, a distance of seventy-nine miles. There were nineteen competitors in the race and seventeen of them finished at times ranging from eight to thirteen and one half hours. The greatest speed attained on this trial was eighteen miles an hour. Numerous other races followed. Since

these contests the growth of the automobile in public favor has been rapid and steady.

Advantage of Rubber Tires. Nearly all automobiles have either pneumatic or cushion rubber tires. Traction engines have spikes or iron strips on their tires to avoid slipping, but the resulting jar would not do for an automobile, so the rubber tire is used instead. The rubber tire has another advantage, it saves power, for no road is perfectly smooth. Even if the bits of gravel average no more than one eighth inch in size, it takes power to lift the wheel over it. If a machine weighs two tons, then there will be 1000 pounds bearing on each wheel. Each time a wheel passes needlessly over an elevation of one eighth inch, 10.4 foot-pounds of work is wasted. Four wheels each having to pass over such an obstacle five times a second at the ordinary running speed would amount to 208 foot-pounds per second, or 12,480 per minute,— almost one half a horse-power. Automobiles are seldom fitted with engines above four horse power, so a saving of half a horse-power is quite an item. The pneumatic tire saves because the pebbles cause little dents in the tire and the axle of the wheel runs in a straight line. Nor is this all, for part of the power that is used in the production of the dent is stored in the elasticity of the tire and as the wheel passes to the point where it is free of the little elevation, the elastic force of the tire helps push against it.

Means of Propulsion. At present the principal means used for propelling automobiles are steam engines, gasoline engines, and electricity. The "Locomobile" is a good representative of the steam carriage and is shown in the accompanying illustration. It effectually conceals a complete boiler and furnace, a water and a fuel supply tank, and a four horse-power steam engine. The water and fuel supply tanks are stowed in the box-shaped part behind the seat, while under the seat is the boiler, furnace, and engine. The boiler,

14 inches in diameter and 14 inches high, is made of copper, and has 298 copper tubes, giving the little boiler 42 square feet of heating surface. The boiler is wound with two thicknesses of piano wire, which gives it great strength. In fact each boiler is hydraulically tested to a pressure of 600 pounds to the square inch. The wire wrapping is covered with asbestos to prevent the radiation of heat. The boiler complete weighs only 105 pounds. The fuel is gasoline and the boiler pressure is controlled by an automatic device which regulates the size of the fire to correspond with the needs of the boiler. The fire may be lighted and the steam pressure raised to 150 pounds inside of five minutes from the time of starting with a cold boiler. When the vehicle is carrying enough water and fuel for a run of 25 miles, the whole affair weighs only 550 pounds.

LOCOMOBILE.

This is one of the steam driven automobiles. It contains a steam boiler and furnace, as well as a four horse power steam engine. Yet the lines of the customary carriage have not been departed from in its construction.

As a Climber. Double engines allow each drive wheel independent rotation. The engine, at a speed of 300 revolutions per minute, develops four horse-power, and the power may be increased to five horse-power if necessary for a short time. On one test run of 72 miles, the cost for fuel was only 17½ cents. The machine is geared to climb very steep hills and has ascended a 36 per cent. in-

cline. The inventor, F. O. Stanley, and his wife, made one of the first long distance runs with a locomobile from Newton, Mass., to the summit of Mount Washington, a distance of 205 miles, at an average speed of 14.1 miles an hour. The grade of the ascent of the mountain averages 12 per cent., and the machine climbed it in two hours and ten minutes.

An explosive mixture of gasoline and air is the power most generally used in France and throughout Europe. A motor of this class carried off the first prizes at the French race in 1894, which did so much to excite interest in the automobile. The application of this power is said to date back to Mr. Pinkus of England. Lenoir of France used it about 1860 and is a pioneer in its use in that country. Some natural disadvantages of gasoline have been largely overcome. Gas engines were ordinarily heavy, but if "adhesion" is a quality greatly to be desired the weight of the gas engine will answer that perhaps as well as the weight of a storage battery, and gas engines are more economical than steam engines. At first there was considerable difficulty in getting a gas engine that would start promptly, but in the best types this has been overcome. Once it was impossible to change the speed of a gas engine without changing the gear, but improvements in the mechanism regulating the explosion have been devised by which instant changes can be made almost as effectively as with a throttle valve on a steam engine. Owing to the high temperature at which gas engines work the escape is necessarily noisy, but to overcome this "mufflers" have been provided

Considerable interest attaches to gas engines just at present because of the infringement suits likely to be instituted. George B. Selden made application for a patent May 8, 1879, for a road engine driven by a hydrocarbon motor, and a patent was finally granted him November 5, 1895. When the patent was applied for there was not much public interest in automobiles in America. Mr. Selden was a

patent attorney and a shrewd one. "Under the law in force up to 1879 an application for a patent could not be considered to have been abandoned if prosecuted within two years after the last official action. By complying with the letter of the law Mr. Selden managed to delay the granting of his patent for sixteen and one half years."* His claim is a broad one, and if sustained will embarrass many manufacturers of automobiles using gasoline engines as a motive power. The use of gasoline presents one advantage. It can be found at almost any country store and renders machines using it as a motive power especially fitted for touring purposes.

ELECTRIC AUTOMOBILE. BUILT BY THE ELECTRIC VEHICLE CO. OF HARTFORD, CT.

It will be noticed that the customary forms of vehicles have been as closely followed as possible, this one being on the lines of the phaeton.

Electric motors were early applied to vehicles, dating back to Davenport, Becker, and Stratingh in 1835, and mention has already been made of others. Despite the great weight of the storage batteries the electric automobile is popular. The electric motor is the simplest form of machine possible. One moving part and a stationary support. It transforms energy with less waste than any other device for the production of mechanical energy yet known. There is no fire, heat, or odor connected with its use, and no danger of an explosion. The speed can be instantly changed by varying the current supplied to the motor. A two horse-power motor at ordinary speed exerts about sixty pounds tractive power. If the necessity

*_Scientific American_, November 24, 1900.

arises this same motor can, without injury, exert a pull of 800 pounds. Such a reserve power is sometimes convenient.

The weight of the storage batteries is likely to be reduced in the near future, for the chemical change necessary for a horse-power-hour requires only about eleven pounds of material. By reducing the weight of the container, the supports for the plates, and the battery fluid, a saving could be made. Batteries are made and used in automobiles furnishing power for from 80 to 100 miles. Such can be recharged in an hour and a half, so it seems that practical utility is nearly approximated.

An automobile truck is being made employing a steam engine to compress air, which is drawn from a reservoir and used as a motive power by the truck. The force required to hold the truck back in going down grades is also used to assist the engine in compressing air. Automobiles using liquid air as a motive power have been exhibited, and the Tripler Company have stated that they are ready to furnish liquid air for them at fifteen cents a gallon. The practical efficiency of such a machine has yet to be demonstrated.

Some remarkable speed records have been made by the automobile. In August, 1897, 105 miles were covered at the rate of twenty-six miles an hour. In July, 1898, this record was raised to thirty miles an hour for 357.3 miles. In a nine days race around France, a distance of 428 miles was covered by the winner in 44 hours 44 minutes and 9 seconds, an average of about thirty-two miles an hour.

Automobile vs. the Express Train. Monsieur Charron of France won, at the Paris Exposition, the International Challenge Cup, June 14, 1900, the course being from Paris to Lyons, 351 miles; time, nine hours nine minutes; average speed, 38.4 miles an hour. The regular express train between those cities, by a shorter route, 318 miles, covers the distance in nine hours. Had Monsieur Char-

ron's route been as short he would have beaten the time of the express train. Another of the contestants made 62 miles an hour for a considerable part of the distance and in some places his speed was over 70 miles an hour, but his machine was broken by an accident which prevented his winning the race. He showed, however, what bursts of speed are possible on an ordinary road, and M. Charron proved that the automobile can maintain a high speed for a long distance.

The question of the use of automobiles in the French army is receiving a good deal of attention. Emperor William of Germany has offered a prize of $20,000 for the machine best adapted for use in military service.

Aerial Navigation.

Although for thousands of years mankind has longed for "the wings of a dove," the Montgolfier brothers' crude balloons were the first practical step toward the realization of the dream of aerial navigation. It was in France that after several unsuccessful experiments Stephen and Joseph Montgolfier constructed a balloon, inflated it with hot air, and gave a successful exhibition of it June, 1783. It does not appear that this balloon carried any passengers. In August of the same year M. Charles, a Parisian scientist of considerable repute, improved upon Montgolfier's idea by substituting hydrogen gas for hot air, and the Robert brothers constructed it for him. In such a balloon, MM. Charles and Robert made a successful ascension, reaching a height of 7000 feet. In November of 1783 Pilatre de Rozier ascended in a Montgolfier hot air balloon. It is generally believed that this antedates the ascension of MM. Charles and Robert. These were the first balloon ascensions and they were made at or near Paris, and France has ever since been keenly alive to the importance of aerial navigation and ready to lend aid to any other project that seemed to promise its successful achievement.

Balloons rise because filled with some gas lighter than atmospheric air. Balloons inflated with ordinary illuminating gas lift about one pound for each thirty cubic feet of their contents. Hydrogen gas has about twice the buoyancy of illuminating gas. The buoyancy of hot air depends, of course, upon the difference between its temperature and that of the surrounding atmosphere. Glaisher and the aeronaut Coxwell are said to have reached an extreme height of 37,000 feet. As for long distance records, John Wise is said to have made the trip from St. Louis, Mo., to Jefferson county, N. Y., 1200 miles, in twenty hours.

Early Ideas of Air Ships. A letter dated May 24, 1784, written by Francis Hopkinson to Benjamin Franklin, suggests that a balloon be made oblong and driven by a wheel at its stern. "This wheel should consist of many vanes or fans whose planes should be considerably inclined with respect to the plane of its motion, exactly like the wheel of a smokejack." It was not until many years afterward that Stevens, Smith, and Ericsson were able to successfully apply the screw propeller here outlined to steam navigation, and it is worthy of note that Professor Langley and Mr. Maxim used this principle in their latest flying machines.

Henri Giffard, the inventor of the "injector," in 1852 made a balloon large enough to carry a steam engine and the machinery to turn a screw propeller. He was actually able to move his air ship fast enough so it could be steered to some extent, and produced the first balloon in any considerable degree dirigible (steerable).

In 1881 the brothers Tissander equipped a balloon with a storage battery and electric motor, and were able to make seven or eight miles an hour with it. Napoleon hoped to make the balloon useful to him in his campaigns and took a ballooning outfit with him into Egypt but it was captured by the British. When Paris was besieged (1870–71) more than fifty balloons were employed to carry persons

out of the city, taking with them carrier pigeons by which messages could be sent back to the besieged. Even fashion plates from Paris for the use of English and American magazines were said to have been sent out in this manner. In 1884, Captains Renard and Krebs used an electric battery and motor to drive a screw propeller seven feet in diameter to propel a balloon 165 feet long, and 27½ feet in diameter. This balloon was to be able to make 12 to 15 miles an hour and was readily manageable in a calm, or even in a light breeze.

The Russian Dirigible Balloon. The Russians have a fairly good dirigible balloon capable of carrying one man. It is that of Dr. K. Danilewsky, Charkov, Russia, who partly fills a balloon with pure hydrogen gas to balance the weight of the operator. In a recent exhibition before Russian officers the balloon was taken out of the barn on his estate in which it was kept, and inflated in a half hour. It ascended, passed out of sight, reappeared in about two hours, gradually approached and alighted within a few yards of the place from whence it started. The balloon is small, requires the service of only three or four men to start it, and when inflated can be carried anywhere by two men. It is propelled by the muscular power of the operator. It seems to be but little influenced by moderate currents of air and the descent is absolutely under control. The Russian officers expressed a high opinion of its value for making a reconnaissance.

Count Zeppelin, an officer of the German army, was attracted to the study of dirigible balloons, primarily to develop a new destructive weapon of war. Fortunately he is a man of wealth, for his experiments are said to have cost him at least $100,000. Count Zeppelin has been working for a long time on an air ship. His device is a lattice framework made of aluminum, 416 feet long, and 38 feet in diameter. It is divided into seventeen compartments, in each of which is a balloon equipped with a safety valve to prevent

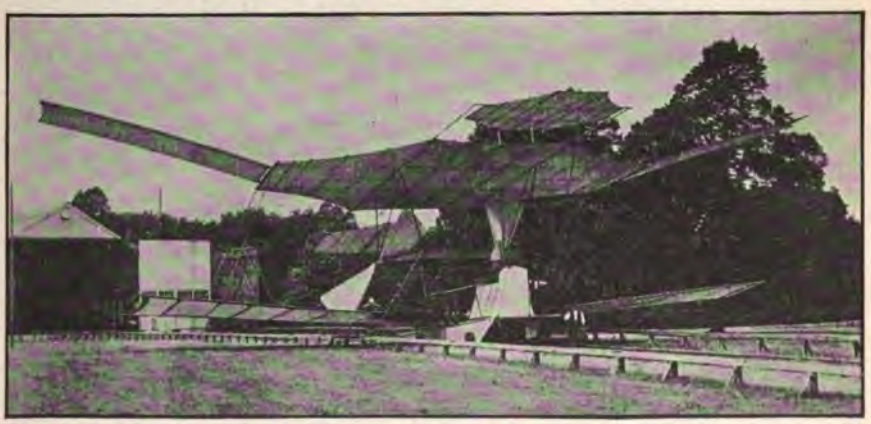
its bursting, should the gas within it expand much under the heat of the sun. When inflated the whole has a total capacity of nearly 400,000 cubic feet and can lift about ten tons. Underneath the balloon, near each end, are two aluminum cars, each about twenty feet long and three feet four inches high. The cars have double floors and the space between them is filled with water ballast, which can be released almost instantly. The air ship with its crew and machinery, all told, weighs about eleven tons. To regulate its buoyancy four of the largest balloons are fitted with outletting valves which can be

COUNT ZEPPELIN'S FLYING MACHINE.

operated from one of the cars. Within the aluminum lattice work is woven a great quantity of aluminum wire, which not only strengthens the frame but furnishes the network usually found about a balloon. The outer cover is water tight, but not necessarily gas tight, and seems to have been chiefly designed to present a smooth surface to the air and reduce skin friction. There are a pair of rudders at each end. Light, strong engines, burning naphtha as fuel, furnish sixteen horse-power to drive screw propellers which supply the motive power. The engines give one horse-power for forty-four pounds of weight and are considerably heavier than those used by H. S. Maxim in his experiments. Under favorable circumstances the air

ship seems to move at the rate of twenty-three miles an hour. A weight sliding on a cable underneath the air ship changes its center of gravity and regulates its poise. When the weight is drawn toward the rear the front rises, and *vice versa*. Count Zeppelin has shown that he has fair control over his air ship and that it possesses moderate speed. It is kept in a floating house on Lake Constance and in alighting rests upon the water, the buoyancy being regulated by the escape valves until it rests easily on the cars without sinking them more than a few inches. Inasmuch as it is said to cost $2380 to inflate it once, it is not likely for some time to be a formidable competitor of present methods of transportation.

Flying machines proper differ from balloons in that they depend for support upon their own efforts without employing buoyant gases for that purpose. Light as air seems, it is yet capable of sus-



MAXIM'S FLYING MACHINE.

taining, for the shortest fraction of time, some weight, just as a stone may be sent "skipping" across the water or a fast skater may pass safely over thin ice that would break under a lighter load moving slowly. Studies made of birds that "sail" show that by changing the slope of their wings they are able not only to sustain themselves

in a strong breeze but actually to make headway against it without, apparently, much muscular exertion. Of the experimenters with flying machines Mr. H. S. Maxim and Professor Langley have been most successful. They each made exhaustive tests of the lifting power of aeroplanes. Of this a kite is a familiar example. Boys know that a kite properly balanced and held by a string in such a way that the wind strikes its under surface, pulls and rises high into the sky against the force of the wind. Mr. Maxim constructed machinery that would turn a vertical shaft. To the shaft he attached at right angles two boards for arms, the whole slightly resembling the fans used during hot weather for ventilating purposes. Setting the boards with the front edge slightly higher than the rear, he rotated them rapidly, measured the power applied to turn them and the lifting power that the boards (aeroplanes) exerted. Maxim found that if the plane were driven at a slant of one in fourteen, it would lift fourteen pounds for every pound of energy used to drive it, and when the slant was made one in twenty, the carrying power increased to twenty pounds for each pound of energy. Different shapes were tried, and it was shown that if the aeroplane were made convex above, concave below, and the front edge sharpened, the lifting power was increased almost two and one half times over that of a flat and blunt board. He next proceeded to experiment with screw propellers and determined the slope of propeller blades that would give the best results. He demonstrated to his own satisfaction that a propeller could be made to drive an aeroplane fast enough so that the lifting power of the latter would carry the machinery required to propel it. He concluded that at the most the power required would not exceed one horse-power for twenty-five pounds weight, and set about to find a motor light enough for his purpose. After trials with oil engines and engines using naphtha in place of steam, he came back to the steam engine and constructed one especially for his pur-

pose. He produced a marvel of lightness and power. For his boiler he used 800 copper tubes one half inch in diameter, an aggregate length of 5700 feet, and with walls only one fiftieth inch thick. They were designed to withstand a pressure of 410 pounds per square inch and tested far in excess of that. To prevent the water tubes from injury from intense heat he kept up a forced circulation of the water within them. The heat was furnished by 7600 naphtha gas burners, whose flames could be instantly controlled. About one pound of gasoline per hour gave a horse-power. The machine was fitted with two compound cylinder steam engines, as remarkable as the boilers. The engines and boilers weighed about 1960 pounds and easily developed 300 horse-power, an achievement in reducing weight never before equaled and hardly considered even possible. The basis of his machines was a wooden platform, light but strong, forty feet long and eight feet wide. Above and fastened to it was a framework of steel tubes. Thirty feet above the platform was the main aeroplane, rather more than fifty feet square and having an area of 2874 square feet. Numerous others were used as wings and rudders, and the total area amounted to about 6000 square feet. All planes were set at the angle that gave the greatest lifting power with the least resistance to motion. The inclination of the side wings and rudders could be instantly changed. The rudders directed the vertical flight. Above the platform were two screw propellers, seven feet eleven inches in diameter, made of yellow pine covered with canvas painted and sandpapered smooth. The thrust of the screws was at the same height as the center of gravity.

The aeroplanes were made of cotton cloth of an especially fine texture. Two thicknesses were employed; the upper one gas tight, the lower slightly porous. The air passing through the lower one filled the space between them and held the lower sheet flat, the object desired, making it almost as efficient as though of wood or

metal, and much lighter. The machine complete weighed about 8000 pounds.

First Trial of Maxim's Machine. The machine was constructed in a building adjoining a large field. From the building a track about one third of a mile long was constructed and laid with rails. Two axles on the bottom of the machine platform were fitted with wheels to run on these rails. Tests showed that the thrust of the screws against the atmosphere gave force enough to easily propel the machine along the track. Not being ready to undertake the task of steering the craft where so many trees and other obstructions were in evidence, an upper set of rails made of timbers three inches by nine inches in section was laid so that they would strike the upper rails and run along underneath those. When all was ready the machine was given two preliminary runs along the track at moderate speed, carrying Mr. Maxim and two assistants. It behaved well and showed a lifting power of 2500 pounds. On the third trial, after running 450 feet at a steam pressure of 275 pounds, it left the lower rails and began to touch the upper ones. At 600 feet it was bearing entirely against the upper rails. At 1000 feet, running at about 50 miles an hour, at a pressure of 310 pounds, its lifting power was so great that it bent the rear axle, threw the wheels out of joint, tore up a hundred feet of track, and wrecked the machine. The dynograph showed that the machine developed at each 100 feet in the run the following lifting power: 700, 1700, 3000, 3700, 3950, 5750, 6600, 6450, 6500, and 8700 pounds. Though the machine was a wreck, man had achieved actual flight, and July 31, 1894, will ever be a red letter day in the history of aërial navigation.

Various Attempts to Fly. Several inventors have constructed models employing aeroplanes and motors, and have proved that such can fly. Lawrence Hargreaves of England has constructed several that have flown hundreds of yards. Professor S. P. Langley of the

Smithsonian Institution has been markedly successful. His first attempt, shortly after that of Maxim, employed aeroplanes driven by screw propellers turned by a small, light steam engine rivaling that of Maxim. Otto Lilienthal of Berlin, soaring, covered distances as great as 1000 and 1500 yards, but his device was a set of wings and a rudder attached to his person. Starting with a run he would spring into the air and depend upon the atmosphere acting upon his aeroplanes. During his experiments he met with an accident which resulted in his death. The nineteenth century has proved the flying machine possible and has left its successful development as a legacy to the twentieth century.

Importance of Air Ships. It needs no argument to prove the value of an air ship that can be used in ordinary weather, and its course directed with certainty. Such a machine would be invaluable for purposes of exploration in "Darkest Africa" or the "Frozen North." A military power enjoying its monopoly would possess an overwhelming advantage over another power numerically stronger. If it were capable of carrying explosives to let fall from a height, it could destroy the most powerful navy afloat. Battleships now carry all the armor they can bear without sacrificing other requisites. Their decks are comparatively unprotected and would be very susceptible to attack from above. It would render war so destructive that it would do more than any other cause to promote universal peace. It could establish communication with blockaded ports or besieged towns, and carry messages to regions inaccessible to telegraph or railroad. The British government would have been only too happy to have possessed one during the heroic defense of Ládysmith, and the whole civilized world would have paid almost any price for an air ship that could have brought authentic news from the imprisoned ministers at Peking.

Water Transportation.

Some years ago it was discovered that by a trick of photography the features of a number of persons might be blended and a composite picture produced. In the steamboat of to-day we have something akin to it, though it is not a blending of features but rather of the inventive genius of a thousand minds. In fact, few mechanical contrivances would better illustrate the theory of evolution.

Evolution of the Steamboat. The average person when asked who invented the steamboat will at once reply, "Fulton." But, with no disrespect to that able engineer, it may be truthfully said that he was only a man who, backed by the wealth and influence of the Livingstons, was able to put in practical shape ideas that had been advanced even centuries before.

Mankind's Progress. It does not detract from Fulton's glory to take this view of his work, and it certainly furnishes a broader, nobler, grander conception of the destiny of the human race to regard such marked improvements as the sum of the efforts of the many rather than the product of an individual genius. If the former view is correct, such improvements show a general advance of the whole industrial army in its warfare with Nature's rude forces.

Just the index alone to the specifications of patents relating to propelling ships by means other than sails, that were filed in the English Patent Office from 1618 to 1866, fills nearly eight hundred closely printed pages. Does not this show something of the wealth of thought that has been lavished on the subject?

It has been said that Blasco De Garray made in 1543 a steamboat and exhibited it before the commissioners of Emperor Charles V. of Spain. This is not easily verified and is not generally credited, but from that time the idea continued to receive increased attention. In 1663 the Marquis of Worcester describes an engine with which he said he could propel a boat against an adverse current.

The First Steamboat. Denis Papin, a French engineer, forced by the Revocation of the Edict of Nantes to leave his country, fled to Hesse, Germany, and was made professor of mathematics at the University of Marburg. He published in 1690 a good description of a fire engine and suggested the application of steam power to boats. Some of his correspondence, recently brought to light, proves that in 1707 he constructed and operated on the river Fulda a boat propelled by paddles moved by steam power. This was one hundred years before Fulton's *Katharine of Clermont*. Papin's experiment was a success but it subjected him to a storm of scorn, ridicule, and abuse. It was made so unpleasant for him that he attempted to go to London in his boat. He descended the Fulda and entered the Weser river, where the boatmen, jealous of their calling and fearing that this strange engine would take from them their means of livelihood, assaulted him and destroyed his boat. He escaped and went to London, where he died three years later. However, the idea was in the atmosphere and numerous experiments were being made by the inventors of the whole civilized world. In 1775 Monsieur Perrier constructed a boat driven by an engine of about one horse-power. It was tried on the river Seine, but his engines were not powerful enough to enable the boat to ascend the river, and it is interesting to note that the inventor ascribed his failure to the use of paddle wheels instead of oars.

First American Steamboat. Mr. James Rumsey of Berkeley county, Virginia, next claims our attention and presents his credentials.

"I have seen the model of Mr. Rumsey's boat, constructed to work against the stream; examined the powers upon which it acts; been eye-witness to an actual experiment in running waters of some rapidity; and give it as my opinion (although I had little faith before) that he has discovered the art of working boats by mechanism and small manual assistance against rapid currents; that the discovery is of vast importance, may be of

the greatest usefulness in our inland navigation ; and if it succeeds, of which I have no doubt, the value of it is greatly enhanced by the simplicity of the work, which, when explained, may be executed by the most common mechanic.

"Given under my hand and seal, in the town of Bath, county of Berkeley, in the state of Virginia, this 7th day of September, 1784.

"GEORGE WASHINGTON."

The poverty of the country was such at the end of the war that Rumsey was unable to find financial backers, so he destroyed his model and went to England, hoping in that older and richer country to find the aid of capital he needed. He took out patents in England, France, and Germany, organized a company, and exhibited a boat on the Thames in 1792. He made little progress and after a hard struggle died Dec. 23, 1793. He had become engaged in a controversy with Fitch, whom he accused of "coming pottering around" his Virginia shop. In London letters written to a friend he speaks of the visits of a Mr. Fulton, a young American engineer who betrayed a very sympathetic and intelligent interest in his plans.

Origin of the Screw Propeller. Thomas Jefferson, writing from Paris in 1785, describes a boat of whose propeller he says: "It is a screw with a very broad or thin worm, or rather it is a thin plate with its edge applied spirally around an axis. This being turned, operates on the air as a screw does. The screw, I think, would be more effectual if placed below the surface of the water." In tracing the evolution of the screw propeller it is well to remember that David Bushnell used it on a submarine torpedo boat in the Revolutionary War, although Bushnell's was turned by hand. The screw is said to be as old as the windmill and is described by Hero of Alexandria. Joseph Bramah took out a patent in England in 1785 for a screw propeller to be placed at the stern of a vessel and the shaft to

be connected directly to the spindle of a rotary steam engine. There is no evidence that he ever put this idea into practice.

John Fitch, in 1786, exhibited on the Delaware a steamboat propelled by means of paddles. The experiment was considered a success. Other boats were built by Fitch and his friends, and one tried April, 1790, on the Delaware river opposite Philadelphia, over a measured course, went at the rate of eight miles an hour. The same boat afterwards steamed eighty miles in a day and ran regularly for three or four months to Trenton, Burlington, Chester, Wilmington, and Gray's Ferry, carrying passengers and freight. "One of these advertisements, taken from *The Federal Gazette* and Philadelphia *Daily Advertiser* of Monday, July 26, 1790, is as follows. It will be seen it was thought sufficiently distinctive to call her the steamboat, since there was none other in the world at that time: —

"'THE STEAMBOAT

Sets out to-morrow morning at ten o'clock, from Arch Street Ferry, in order to take passengers for Burlington, Bristol, Bordentown, and Trenton, and return next day.

'Philadelphia, July 26th, 1790.'"*

The boat steamed in the course of the season 2000 or 3000 miles, but was laid up because there was not enough business to justify the expense of running it.

In 1791, at the request of Mr. Vail, United States consul at L'Orient, France, Fitch went over there for the purpose of building steamboats, but the necessary workmen and materials could not be obtained. Mr. Vail afterwards stated that he showed the plans and description of Fitch's steamboat to Robert Fulton, who visited him in France.

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* Preble's "History of Steam Navigation."

Efforts of the Early Inventors. In the light of the present it would appear that the steam engine had not reached that degree of perfection that rendered the steamboat practicable. Fitch died poor and disappointed. In his autobiography he said, "The day will come when some more powerful man will get fame and riches from MY invention; but nobody will believe that poor John Fitch can do anything worthy of attention."

In 1789 Mr. Patrick Millar exhibited a steamboat on the Clyde canal. It appears to have been driven by paddle wheels and to have made seven knots an hour. It was a pleasure boat used simply for experimental purposes, and soon the engines were taken out and the boat returned to its original work.

The first United States patent applied for was that of Nathan Read of Salem, Massachusetts, who, in 1790, asked for a patent on a steamboat to be propelled by paddle wheels. Later, on reading "The Transactions of the Royal Society," he found mention of an experiment made many years before in France with paddle wheels and supposed that would debar him from securing a patent, so withdrew his petition. Fulton obtained his patent for paddle wheels twenty years after Read withdrew his application. August 26, 1791, the first United States patents were issued to Read for a multitubular boiler, and to Fitch, Rumsey, and Stevens for different applications of steam to boats.

The Earl of Stanhope in 1795 exhibited a steamboat propelled by two gigantic paddles shaped like duck's feet, made to close as they were moved forward and spread out as they were pushed backward. He attained with his boat a speed of about three miles an hour. After Fulton's death it was discovered that he had corresponded with the Earl of Stanhope. Had he found in the earl the wealthy backer that in after years he found in the Livingstons, the first commercially successful steamboat line might have been established in England instead of on the Hudson.

"Elijah Ormsbee, a carpenter by trade, an inventor by birth, and a native of Connecticut, is said to have moved a boat successfully by steam." Ormsbee's experiments were in the vicinity of Providence, Rhode Island. He borrowed a "long boat" from the ship *Abigail*, a copper still from a friend, and constructed a boat that moved by means of goose-foot paddles. The experiment was witnessed by many people of Providence and Pawtucket about 1794. It has been claimed that Mr. Daniel French, who afterward saw the machinery, had it explained to him, and later made Mr. Fulton familiar with it.

ROBERT FULTON.

About the same year Captain Samuel Morey of Connecticut is said to have propelled a boat from Hartford to New York city at the rate of five miles an hour, carrying on board John C. Stevens, several members of the Livingston family, and others. This boat was propelled by a stern wheel. Beyond question, he in 1797 exhibited on the Delaware a steamboat with paddle wheels on the sides and ran it from Bordentown to Philadelphia. Fulton's *Clermont* closely resembled Morey's boat. Captain Morey was an educated man and expended what was then a large fortune in scientific experiments. He corresponded and exchanged visits with Fulton and had taken out several patents for steamboats before Fulton's *Clermont* appeared on the Hudson. Captain Morey always maintained that Fulton copied his plans and abused his confidence.

Rumsey's first boat was propelled by directing a jet of steam

through the stern against the water. In Fitch's first boat water was drawn in at the bow and discharged at the stern, but later he moved it by paddles fixed at the stern. In 1796 Fitch tried the screw propeller, and if not the first to actually move it by steam was at least one of the first. "The experiment was tried under the patronage of Robert H. Livingston, as certified to by John R. Hutchings, General Anthony Lamb, and William H. Westlock. It was made with a screw propeller, the vessel used was a yawl, about eighteen feet in length and having six feet beam, and steered at the bow with an oar. The boiler was a ten-gallon iron pot, with a thick plank lid firmly fastened to it by an iron bar placed transversely. The cylinders were of wood, barrel shaped on the outside, straight on the inside, and strongly hooped. Steam was raised sufficiently high to send the boat once or twice around the pond, when more water was needed to generate steam for a new start. The time was the summer of 1796, and the scene of the experiment was 'The Collect,' a fresh-water pond in New York city, near what is now called Canal street. The pond has been drained, and its site, covered with houses, is now in the heart of the city." *

Chancellor Livingston, American minister to France, had for some years been interested in the application of steam to boats. He made the acquaintance of Robert Fulton, and in 1803 they launched a steamboat on the river Seine. The boat was so frail that when the engines were placed aboard they broke through the bottom and the boat sank. A larger boat made in 1804 was so slow as to be a failure. Napoleon appointed a committee from the Institute to investigate Fulton's scheme and report upon it. When the adverse report was handed in it is said he appeared disappointed and exclaimed, "It is a pity." His navy was vastly inferior to that of Great Britain and he had been anxiously seeking for something that

* Preble's "History of Steam Navigation."

would make his landsmen drafted into the French navy, the equal of the British sailors. After Fulton's unsuccessful experiments on the Seine, he went to England to inspect the boat *Charlotte Dundas*, built by Miller, Taylor, and Symington, and which was in successful operation upon the Clyde canal. Of this visit Symington has said: "In compliance with Mr. Fulton's earnest request, I caused the engine fire to be lighted up, and in a short time thereafter put the steamboat in motion, and carried him from Lock Sixteen, where the boat then lay, four miles west in the canal, and returned to the place of starting, in one hour and twenty minutes, to the great astonishment of Mr. Fulton and several gentlemen, who at our offset chanced to come on board." The *Charlotte Dundas* had a double-acting Watt engine and a stern paddle wheel. The power was transmitted by a connecting rod attached to the crank of the paddle shaft. She was employed to tow boats on the Clyde canal and did the work successfully, but was abandoned because the canal authorities considered the waves she set in motion destructive to the canal banks.

Aided by Chancellor Livingston, Fulton purchased an engine of Boulton and Watt in 1806 and shipped it to America. The state of New York had already, April 3, 1803, conferred upon Livingston and Fulton the privilege of navigating for twenty years, by vessels propelled by fire or steam, all the waters within its boundaries upon condition that they should propel a boat of twenty tons burden up the Hudson at the rate of four miles an hour. After considerable delay the *Clermont*, a boat 130 feet long, 18 feet wide, drawing six feet of water, was launched at New York and the Boulton and Watt engine that had been lying at New York between Canal street and the Battery for some months, held by the carriers for non-payment of freight, was installed. It was a low pressure engine with a cylinder twenty-four inches in diameter and a three-foot stroke, and it turned two side paddle wheels fifteen feet in diameter dipping

two feet in the water. On August 7, 1807, the *Clermont* with Fulton, her crew, a few friends, and six passengers left her berth in the presence of an incredulous and jeering crowd and proceeded on her memorable voyage up the Hudson. She made the trip of 150 miles in thirty-two hours, a rate of nearly five miles an hour, and complied with all the requirements necessary to hold the privilege to the navigable waters of New York state for Livingston and Fulton. The excitement the appearance of the boat produced can be better imagined than described. Mails were slow, there was no such thing as telegraphic communication, and the people along the route were not prepared for the appearance of the strange monster. The crews of many of the passing boats were much alarmed even in the daytime, and at night as she moved along, emitting a cloud of sparks from her chimneys and accompanied by the rumbling and roaring throb of her engine, she struck terror to the hearts of the superstitious. "Whole crews prostrated themselves upon their knees and besought Divine Providence to protect them from the horrible monster that was marching on the tides and lighting up its pathway by its fires." Writers of that time do not agree as to the name of the boat. Some state that it was called the *Clermont*, after Chancellor Livingston's residence; others that it was called *Katharine of Clermont*, after Fulton's wife, Katharine Livingston.

THE "CLERMONT'S" FIRST VOYAGE.

Development of Steam Shipping. A regular line was established between Albany and New York. The fare by stagecoach be-

tween the two points was $12, but Fulton's boats were soon carrying passengers for $7 and the price in a few years was reduced to $3. Fulton's name has become so closely linked with the steamboat because his line was a financial success, made so by the wealth, influence, and enterprise of the Livingstons aided by the valuable franchise conferred upon them by the state of New York. Numerous inventors had made steamboats before the *Clermont* was launched and some of them were speedier, notably those of Fitch, Colonel John Stevens, and Symington.

Fulton's first United States patents, issued in 1809 and 1811, covered only a few points relating to the attachment of paddle wheels to axles and cranks to engines. August 26, 1791, a United States patent signed by George Washington, president, and Thomas Jefferson, secretary of state, was issued to John Fitch "for applying the force of steam to cranks, paddles for propelling a boat or vessel through the water." Fitch's patent was granted for fourteen years and it expired before the *Clermont* was launched. Fulton was an able engineer and had devised improvements in machinery for sawing marble, making rope, spinning flax, and making excavations, and he had given considerable study to the improvement of canals. He was also a portrait painter of considerable ability.

Colonel John C. Stevens of Hoboken, N. J., who devoted considerable time and money to experiments with steamboats and steam engines and was later to become identified with railroads, in 1789 petitioned the New York legislature for a grant of the exclusive right of steam navigation of the waters of that state but it was refused him and later given to the Livingstons. The Stevens family had constructed several steamboats prior to 1807, some of them better than any at that time existing. One of their later ones, the *Phœnix*, a paddle wheel steamer, was ready only a few days later than the *Clermont*, but the franchise granted Fulton and Living-

ston precluded Stevens from operating it on New York waters. Later, with characteristic courage, he placed it in command of his son, Robert L. Stevens, who started along the coast of New Jersey around Cape May and up the Delaware to Philadelphia. This was the first appearance of a steam vessel on the ocean. Stormy weather was encountered but the *Phœnix* was able to make a harbor when sailing vessels were blown out to sea, and arrived safely at Philadelphia. It was employed for a long time to transport passengers and freight on the Delaware river. Improvements in steam engines increased the efficiency of the steamboat and soon they were found on the principal inland waters of America. The first to appear on the St. Lawrence was the *Accommodation* launched in 1809, which carried passengers from Montreal to Quebec for $8 and from Quebec to Montreal, against the stream, for $9. In 1811 a line was established between Pittsburg and New Orleans.

In Great Britain. In 1812 Henry Bell of Glasgow launched the *Comet* and established the first commercially successful line in Great Britain. Following is a copy of the original advertisement: —

"STEAM PASSAGE BOAT. The Comet. Between Glasgow, Greenock, and Helensburgh, for passengers only. The subscriber having, at much expense, fitted up a handsome vessel to ply upon the RIVER CLYDE BETWEEN GLASGOW AND GREENOCK, to sail by the power of wind, air, and steam, he intends that the vessel shall leave the Broomielaw on Tuesdays, Thursdays, and Saturdays, about midday, or at such hour thereafter as may answer from the state of the tide; and to leave Greenock on Mondays, Wednesdays, and Fridays, in the morning, to suit the tide.

"The terms are for the present fixed at 4s. for the best cabin, and 3s. for the second; but, beyond these rates, nothing is to be allowed to servants or any other person employed about the vessel.

"The subscriber continues his establishment at HELENSBURGH BATHS the same as for years past, and a vessel will be in readiness to convey passengers in the Comet from Greenock to Helensburgh.

"Passengers by the Comet will receive information of the hours of sailing by applying at Mr. Housten's office, Broomielaw; or Mr. Thomas Blackney's, East Quay Head, Greenock.

"HENRY BELL.

"Helensburgh Baths, Aug. 5, 1812."

Russia introduced steam navigation in 1815–1816, but earlier than that she placed an order for a steamship with a company in the United States which constructed the *Emperor Alexander* for her. Great Britain's command of the sea during the War of 1812 prevented the departure of what would have been the first steam vessel to cross the Atlantic, and it was used as a coasting steamer between Portland and Boston. As early as 1826, Russia had a steam warship.

The first steam vessel to cross the Atlantic was the *Savannah*. Built at New York, launched August 22, 1818, of 380 tons burden, she was originally intended as a sailing packet between New York and Liverpool. She was fitted with sails and paddle wheels, and made the passage from New York to Savannah in 1819 in seven days, where she took President Monroe and his party on board for a trial trip. On May 26, 1819, she sailed from Savannah for Liverpool. The log books of several ships contain notices of having spoken her. One supposed she was on fire and tried to afford relief but could not catch her. Off the coast of Ireland the revenue cutter *Kite* chased her for several hours, supposing her to be either on fire, or a most suspicious craft. Several shots were fired at her before she stopped her engines, and the revenue officers were greatly surprised at the strange craft when they came on board. She arrived in Liverpool after a voyage of twenty-five days, having used her engines but eighteen days for fear of giving out. The *Savannah* was the subject of many strange rumors,—one that she was a craft especially designed to effect the escape of Napoleon from St. Helena. From Liverpool she proceeded to Copenhagen, Stockholm, and St.

Petersburg, being visited at each port by a curious crowd; while at Kronstadt the Emperor of Russia paid her a visit. She returned to Savannah, having made the voyage in excellent condition. Later she was wrecked off the coast of Long Island.

The importance of steam navigation soon came to be generally recognized, and lines of steamboats were plying upon the inland waters of America, between Ireland and Great Britain, and between Dover and Calais. In 1825 the British ship *Enterprise* steamed from London to Calcutta, and was the first to steam around the Cape of Good Hope. However, steamship lines between British and Indian ports were restricted chiefly to carrying passengers, for the great amount of coal required for the long voyage occupied so much room that there was little left for profitable freight.

Iron Ships. In 1820 the *Aaron Manby* was launched at a British shipyard. She was the first iron steamer and the first steamer to sail directly from London to Paris. By 1832 iron ships were common. They were stronger, lighter, and were the first vessels constructed with water-tight bulkheads. In 1831 there was built at Quebec the *Royal William* and the following year this steamer, the third to cross the Atlantic ocean, was taken to Montreal, fitted with engines, and made the voyage to London. Her appearance was so unusual that upon encountering a British warship she was fired upon and forced to lie to until the naval officers could satisfy themselves there was nothing wrong with her. She had no cargo but coal, and used the greater part of that in making her voyage. While on the Thames she was sold to the Spanish Government, and was the first steam war vessel possessed by that nation. Prior to 1838 it was generally supposed that a steamer in crossing the Atlantic would require so much coal that there would be little room left for passengers or paying freight.

Opening of Transatlantic Lines. As early as 1832 Dr. Junius

Smith, an American residing in London, began to agitate the question of a line of transatlantic steamers. A trip from London to New York which consumed fifty-four days, and the return, thirty-two days, brought the need forcibly to his notice, when, according to his ideas, a steamship should have made the time in fifteen or sixteen days. His plan excited general ridicule and the strenuous opposition of those interested in sailing vessels, who, from self-interest, would naturally oppose such schemes. So conservative were the people that the utmost difficulty was experienced. The Duke of Wellington replied to Dr. Smith that he "would give no countenance to any scheme which had for its object a change in the established system of the country." However, Dr. Smith pluckily kept at it, borrowed influential names and by such aid secured other names until finally he had a list of responsible gentlemen who would agree to become directors in his company. The company, known as the British and American Steam Navigation Company, was organized, the stock subscribed, and the construction of the *British Queen*, of 2400 tons, what was then an exceedingly large vessel, was begun. The line was intended to run from London and Liverpool to New York.

Meantime a rival company was in the field. The Great Western Railway was constructed from London to Bristol about 1835. At one of the meetings of the directors the celebrated engineer, Brunel, proposed building steamships and connecting Bristol directly with New York. The idea was treated as a joke, but the authority of the engineer prevailed and a comparatively large ship known as the *Great Western* was constructed. This line was to run in opposition to that of Smith's, and the *Great Western* was to be completed before the *British Queen*. Not to be outdone, Smith's line chartered a schooner rigged steamer called the *Sirius* and employed her until their own vessel could be completed The *Sirius* left Cork on her first voyage April 4, 1838, and arrived off New

York harbor April 22, making the trip in eighteen days. This was the first trip made in the interests of an established transatlantic line. The *Great Western* sailed from Bristol four days later than the *Sirius* and arrived in New York April 23, actually tying up at the wharf only a few hours later than the *Sirius*, for the latter vessel, in trying to make the harbor without a pilot, grounded and was delayed off Sandy Hook. Their appearance at New York created a sensation and marked a new epoch in transportation. This was not so long ago but that many people are still living who witnessed the arrival of these steamers at New York. If they be compared with the largest steamers at the close of the century the advance appears startling. The *Sirius*, which made the first voyage in the interests of an organized transatlantic company, was of about 700 tons burden. The *Deutschland*, the fastest steamer of the Hamburg-American line, the greatest transportation company in the world, has a displacement of 23,000 tons. The *Sirius* in her voyage made 7 knots an hour; the *Deutschland*, 23½ knots an hour. The engines of the *Sirius* developed about 320 horse-power; those of the *Deutschland*, 36,913 horse-power. The first was moved by paddle wheels aided by masts and sails; the second by two manganese bronze screw propellers, 23 feet in diameter, each attached to the end of a hollow nickel steel shaft, 130 feet in length and more than 2 feet in diameter. Steam is furnished the *Deutschland* by 16 Scotch boilers, with a working pressure of 225 pounds per square inch, heated by 112 separate furnaces, burning 572 tons of coal a day. In her record run she averaged 1.45 pounds of coal per horse-power-hour. The engines of the *Sirius* worked with a pressure of 53.4 pounds per square inch, and her furnace consumed one ton of coal in one hour and thirty minutes. She carried forty-six passengers. The *Deutschland* has sleeping accommodations for 1320 persons, rather more

people than are found in the average country town. At her best the *Siriŭs* could do about 225 knots a day: the new ship has a record of 584 knots in 24 hours. The *Sirius* occupied 17 days on her return trip, ran out of coal and burned anything that could be spared. The *Deutschland*, leaving New York September 5, 1900, on her eastern trip, crossed in five days, seven hours, and thirty-eight minutes, her engines at times developing nearly 38,000 horse-power. The engines of the *Deutschland* are each of the 6-cylinder, quadruple expansion type: two high pressure cylinders, each 36.64 inches in diameter; first intermediate cylinder 73.67 inches in diameter; second intermediate cylinder 104.61 inches in diameter. The common stroke is 72.89 inches. To produce the steam required to drive her enormous mass at the rate of 28 statute miles an hour it is necessary to expose nearly two acres (84,250 square feet) of her heating surface to the action of the fire of 112 furnaces. Twelve rings or collars on each shaft, working against bearings or thrust holes, hold the shaft in place and prevent the propellers from pushing the engines out of the ship.

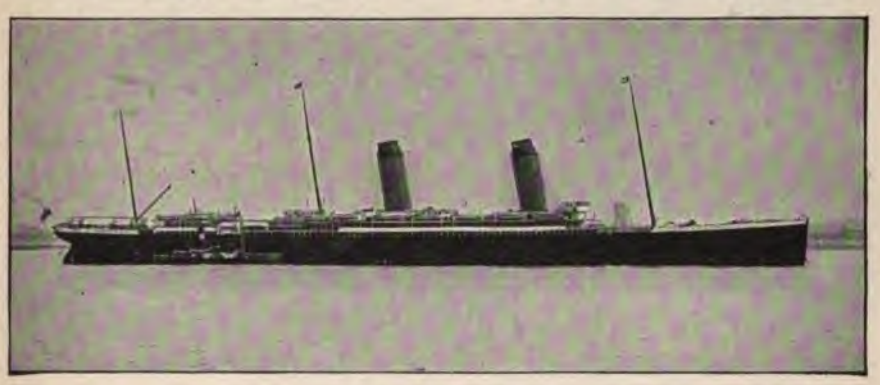
Contrast with the Present. It is estimated that it costs $100,000 to send the *Deutschland* on one round trip. The coal alone for one voyage costs about $15,000. She has a crew of 550 men, of whom 240 are required to care for her engines and machinery. The enormous engines and the necessary supplies take up so much room that the *Deutschland* has room for only about 600 tons of freight and carries practically none. Her furnaces burn in one day as much coal as the *Sirius* could carry if her whole cargo were given up to it. The *Deutschland* is essentially a passenger steamer and everything has been done to make her attractive. She has a gymnasium, a hospital, library, printing office, pianos, flowers, an electric lighting plant with about 2000 lights in the circuit, a restaurant forty feet above the water where the passengers can obtain meals at any

time. In the grand saloon 500 persons can be seated at the table at one time. Costly paintings and decorations add to the general attractiveness, and an ocean voyage has been robbed of its most disagreeable features. Every provision for safety that the ingenuity of man can devise has been made. She has a cellular double bottom divided into twenty-four tanks, and the inside of the hull proper is divided into twenty-one water-tight compartments, while twenty-six lifeboats provide for any emergency. So popular has the *Deutschland*, the fastest steamship of the nineteenth century, proved, that on one western voyage $143,000 was collected for passenger fares.

The "Great Eastern." After the trips of the *Sirius* and *Great Western* had proved the practicability of the scheme other transatlantic lines were soon established. The Cunard line in 1840, whose proud boast is still that they have never lost a passenger; the Bremen line in 1847, the Havre line in 1848. The Collins line followed in 1850, and soon steamships were plowing certain well recognized routes of travel. By 1852 it had been demonstrated that steamers running from England to Australia usually lost from $5,000 to $50,000 on a voyage, owing to the necessity of stopping often to replenish their coal bunkers, such stops taking them out of the shortest lines of travel and consuming so much extra time that the fastest sailing ships made as quick passages and at less expense. Studying this problem, Brunel, the great engineer, came to the conclusion that a vessel of 25,000 tons capacity could carry ample coal supplies and have room enough left for freight and passengers to operate at a profit. He interested capitalists, organized the Eastern Steam Navigation Company with a capital of £1,200,000, and work on the *Great Eastern*, until 1899 the largest ship in the world, was begun May 1, 1854. The hull was made double, at that time an unusual construction, the outer and inner shells being two feet ten inches apart, with partitions running lengthwise and crosswise

dividing the space into water-tight cells about six feet square. The interior of the ship was divided by transverse bulkheads (partitions crossing) into twelve water-tight compartments below the lower deck and nine compartments above. Two of these compartments might be filled with water without endangering the safety of the ship. Two bulkheads extending from the bottom of the ship to the upper deck ran lengthwise for about 350 feet. To reduce the draft she was built with a flat bottom without any keel. About 30,000 iron plates, averaging ten feet by two feet nine inches, and three fourths inch thick, and 2,000,000 rivets, the whole weighing about 9000 tons, were used in the construction of her hull. The vessel when completed had an extreme length of 692 feet; breadth across the paddle boxes, 118 feet; breadth of hull, 83 feet; depth from bottom to upper deck, 58 feet; six masts, two paddle wheels 56 feet in diameter, weighing 185 tons, or more than Fulton's first steamboat. Ten boilers heated by 112 furnaces furnished the steam to turn the paddle wheels and a screw propeller twenty-four feet in diameter. Her draft when empty was fifteen feet six inches; when fully laden, thirty feet. The vessel was so long that she could not be launched stern first as is customary, so 1400 piles were driven in the mud along the river bank and she was built and launched sideways. They first tried to launch her November 3, 1857, but moved her only six feet. Several unsuccessful trials followed, and it was not until January 31, 1858, that she was afloat. She at that time had cost $3,555,100. In 1858 the company became financially embarrassed, was dissolved, and a new corporation, called the Great Ship Company, formed, and the ship completed. When fully equipped her displacement was about 27,000 tons and her engines developed about 12,000 horse-power. She had accommodations for 800 first class passengers, 2000 second class, 1200 third class; or more than any ship ever built. However, on her first voyage she carried only

thirty-eight passengers and eight guests. She left Southampton June 17, 1860, and arrived at New York in eleven days and two hours, having steamed 3188 knots, at an average speed of twelve knots an hour. Her greatest speed was about 14½ knots an hour. She consumed 2877 tons of coal. Even at that time other steamers were speedier than she. The *Baltic*, of the Collins line, the same year ran from New York to Liverpool in nine days, thirteen hours, and thirty minutes. The greatest service the *Great Eastern* performed was in laying the Atlantic cable, for which work her great bulk and steadiness in rough seas especially fitted her. In 1875, when put in dry dock that her bottom might be cleaned, it was esti-



THE "OCEANIC."

mated that from 52,000 square feet of her hull, rather more than an acre, mussels six inches in thickness and weighing about 300 tons were removed, or nearly as much as the entire tonnage of the *Savannah*, the first steamer to cross the ocean. The *Great Eastern* was not a financial success. In 1880 the directors of the company to which she belonged reported she had run them in debt between $40,000 and $50,000 annually. She was sold to a man who used her for exhibition purposes. Later she was broken up and sold for old iron.

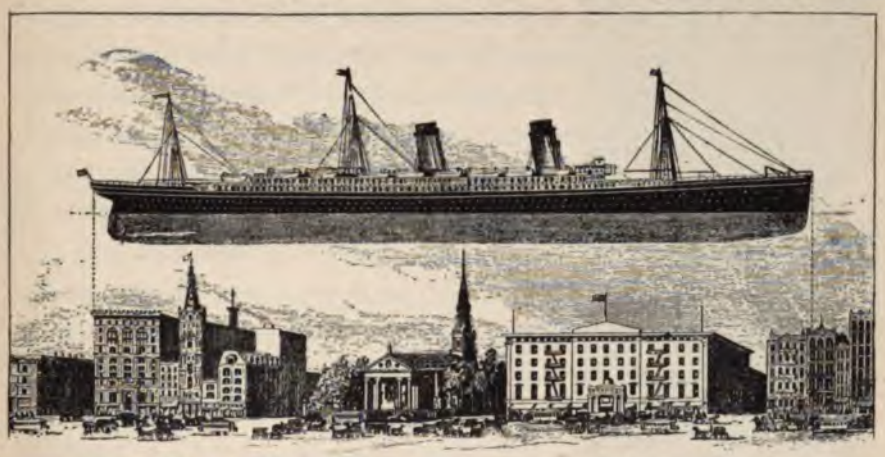
The "Oceanic." It was not until 1893 that a larger ship than

the *Great Eastern* was constructed. Then the *Oceanic* was launched with a total length of 704 feet, 12 feet more than the *Great Eastern*, and a displacement of 28,500 tons to the 27,000 tons of the other. The *Oceanic* has five steel decks running from stem to stern. She is made with a double bottom, the intervening space being from five to seven feet. The plates range in thickness from one to one and one half inches. She has twin screw propellers turned by triple compound engines of 28,000 horse-power. She can accommodate 410 first class passengers, 300 second class, 1000 third class. The *Oceanic* was constructed by the White Star line at a cost of $5,000,000, with the avowed object of furnishing a steady sea-going boat that might be depended upon to arrive in port on schedule time irrespective of the weather. Extreme speed was not expected of her, yet she can make 21¼ knots an hour. Larger ships are now being constructed, and it is likely the twentieth century will see others yet larger and faster. The following table gives the principal dimensions of the largest ships.

LAUNCH OF THE "OCEANIC."

Line	Steamship	Launched	Length Feet	Beam Feet	Draft Feet	Displacement Tons	Horse-Power	Speed
Great Ship Company	Great Eastern	1858	692	83	30 / 25½	31,000 / 27,000	12,000	14.5
American	City of Paris	1889	560	63	26½	15,000	20,000	20.25
White Star	Teutonic	1890	585	57½	26	13,800	18,000	19.50
Cunard	Campagnia	1893	625	65	28	19,000	30,000	22.1
American	St. Paul	1895	554	63	27	16,000	20,000	21
North German Lloyd	Kaiser Wilhelm der Grosse	1897	649	66	29	20,000	28,000	22.62
White Star	Oceanic	1899	704	68	32½	28,500	28,000	21.25
Hamburg-American	Deutschland	1900	686	67	28	23,000	36,913	23.36
North German Lloyd	Kaiser Wilhelm II.	?	705	?	?	26,000	38,000	?
White Star	?	?	750	?	?	32,000		?

The "Turbinia." The nineteenth century has left the twentieth century the development and perfection of the steam turbine. In all engines of the piston principle there are many reciprocating parts that must be stopped at the end of each stroke and started the other way. There is great strain attendant upon this, and the energy required for its performance is sheer waste. Various methods are employed to overcome this strain; for example, where four engines are attached to a propeller shaft the cranks are turned at right angles



THE "OCEANIC" COMPARED WITH BROADWAY BUILDINGS.
From "The Progress of Invention in the Nineteenth Century."

to each other, like four spokes in a wheel, and the reciprocating parts of one engine balanced as much as possible by those of another. It was the shock and strain of reciprocating parts that recently nearly wrecked the St. Paul. An accident to the propeller set the machinery to racing at high speed, and the centrifugal force of the unbalanced parts soon wrecked the machinery and made the engine room look as though a torpedo had struck it.

Parsons Steam Turbine. The losses due to reciprocating parts are well understood and have engaged the attention of many able inventors who have constructed engines without such parts. Nearly

2000 patents have been granted in the United States alone for such termed rotary engines. Of these Parsons steam turbine is at present the best advertised because applied in 1897 to the yacht *Turbinia*. It drove her at the rate of 32¾ knots an hour, which was then considered a wonderful speed, and later, applied to the *Viper*, has enabled her to cover a measured mile at the rate of 37.1 knots an hour, or 42.67 statute miles. In reciprocating engines the piston is forced back and forth, as steam is applied to each side of it, but in the turbine a disc bearing vanes or flanges, against which steam impinges, revolves continuously in one direction like a windmill, and there is no stopping and starting of pistons, cross-heads, slide valves, etc. Roughly, the Parsons steam turbine may be said to consist of a cylinder with inside rings or diaphragms through which steam is guided and directed against moving blades fixed to a revolving shaft, turning something like a windmill, with slats like a Venetian blind. There may be a series of such rings and blades within the cylinder. Steam, passing through the first, acts upon the first set of blades and so on through all.

TEUTONIC IN DRY DOCK. Showing Screw Propellers.

The De Laval turbine consists of a steel wheel with a series of vanes or buckets at its outer rim, against which jets of steam are directed, causing the wheel to revolve. A speed of 30,000 revolutions a minute has been reached with the De Laval turbine, and it is peculiarly adapted to running high speed dynamos. One precaution that has to be taken with turbines moving at such high speed is that the rotating parts must move about their absolute center of mass

and not their geometrical center of figure. Ordinary workmen cannot perform such infinitesimally fine work as to construct bearings which accomplish this, so it is necessary to make some arrangement by which the machine will attend to this adjustment for itself. Parsons makes the bearings of several concentric bushings fitting over each other loosely and fills the small space between them by forcing it full of oil under pressure. Such fittings allow the shaft to displace the bearings ever so slightly in the direction required. De Laval mounts his wheel on a long slender spindle, that the latter may spring enough to give the desired result, but a large number of De Laval's spindles have broken, showing the method is imperfect, for a speed of 17,000 revolutions per minute means over a million changes of stresses an hour, and this is enough to worry the life out of the best steel in a comparatively short time.

Since the turbine moves continuously in one direction it has the marked advantage of being free from the vibrations inherent in other engines that use reciprocating parts. The thrust of the propeller that with ordinary engines is taken up by collars and thrust blocks is balanced by the pressure of the steam against the turbine and the friction saved. The engines of turbines with all their auxiliary gear weigh less per horse-power than in the reciprocating type, but greater boiler surface is necessary to produce the vast amount of steam required, and the increased weight of boilers materially reduces the credit for weight saved by the engines.

The "Viper," the fastest vessel of the nineteenth century, showed on her various trials as high as 35½ knots, or practically 41 statute miles an hour, and covered one mile at 37.1 knots an hour. She has four propeller shafts, two on each side driven by two duplicate engines, one on each side. The two innermost propeller shafts have attached an additional small reversing turbine to which steam is admitted when the vessel is reversed, and which revolves

idly with the shaft when the vessel goes ahead. To reverse the vessel, steam is cut off from the propelling turbines and applied to the reversing turbines. No thoroughly satisfactory means has been devised for reversing the regular turbine. It is generally believed that steam turbines are not economical users of coal. The *Viper* has a displacement of 385 tons. Running at 31.118 knots she burned 19,846 pounds of coal per hour. The *Albatross* is a boat of the same class fitted with reciprocating engines and having a displacement of 384½ tons. Running at the rate of 31.552 knots, she consumed 17,474 pounds of coal per hour, showing economy of 2372 pounds of coal in favor of the reciprocating engine.

CANALS.

Birthplace of Civilization. The origin of the canal is lost in the mists of antiquity that surround the valleys of the Nile and the Euphrates, rival claimants for the credit of the birthplace of civilization. The explorations conducted by the University of Pennsylvania in the valley of the Euphrates have brought to light indisputable proof of the existence of a high civilization there thousands of years before the beginning of the Christian era. The country supported a dense population, having colleges and libraries well established more than a thousand years before Abram and his family left "Ur of the Chaldees to go into the land of Canaan." The lower valleys of the Euphrates and Tigris rivers were connected by a network of irrigating ditches, some of which reached the dignity of canals large enough to afford passageway for the boats of the period. The strategic value of the canal was recognized, and canal centers were commanded by towers built to defend them, for the water supply was the life of the country, and when more warlike and less enlightened tribes from the north invaded the land and broke down the dams and canals the country lapsed into that state of decay and barrenness that characterizes it to-day.

De Lesseps Anticipated. The valley of the Nile has also an interesting history. Egyptologists have shown that at different times it has been connected by a canal with the Red Sea, probably before Joseph "went down into Egypt." The valley of the Nile, like that of the Euphrates, depended upon irrigation, and what more natural than the development of a canal for commercial purposes from an irrigating ditch?

Chinese Canals. The Grand Canal of China, in operation to-day, and bearing the burden of a large part of its inland commerce, connects the rivers Pei-Ho and Yang-tse-Kiang. The canal is about 560 miles long and with the connecting rivers furnishes an inland waterway of more than 2000 miles, an important consideration in a country where the religion of its people will not allow railroads to cross the graves of their ancestors. It is interesting to note that although the country is supposed to have a population of about 400,000,000 souls it has only about 600 miles of railroad and 4000 miles of telegraph line. Small wonder that millions of its inhabitants never heard of its late war with Japan!

The little kingdom of the Netherlands represents a victory wrung by man from the forces of nature. Much of its surface lies below the level of the sea, which is held back by powerful embankments. The construction of canals was begun there in the twelfth century and they have been developed to such an extent that those for drainage and communication now have a total length of 1,907,170 miles, while the area of the country is only 12,656 square miles.

The Amsterdam Canal. One of the most remarkable feats of modern engineering was the construction of the Amsterdam Canal, connecting that city with the North Sea. The canal is 15½ miles long, 88 feet wide at the bottom, 197 feet wide at the top, and has a depth of 23 feet of water. Its level is 20 inches below that of the sea at low tide and this has necessitated the building of an artificial

harbor, dikes, gates, and enormous centrifugal pumps, the latter being able to discharge 440,000 gallons of water per minute.

Baltic and North Sea Canal. Germany has 1452 miles of canals and 1371 miles of canalized rivers. The most important canal is the Baltic and North Sea Canal, opened in 1895 and costing $40,000,000; it runs from Kiel on the Baltic Sea, southwesterly across the isthmus which connects Germany with Denmark, to the south of the river Elbe. It is 61 miles long, 85 feet wide at the bottom, 196 feet wide at water level, and has a depth of 29½ feet of water, affording a passage for the most powerful warships of the German navy. It was built by the Government and its strategic value was its chief consideration. It gives Germany an outlet to the sea without having to brave the dangers of a stormy passage around Denmark; no small consideration, for from 1858 to 1885 the storms and ice floes wrecked 2800 vessels, and from 1877 to 1881, 708 lives were lost on this route.

Theoretically, the whole canal is at the Baltic Sea level. It is practically unaffected by the tides, but the rise and fall of the North Sea on the Elbe is so high that tidal locks have to be established. Storm gates are required on the other end twenty-five days in the year, but the tide locks at the Elbe will be kept closed except during three hours of ebb tide. These locks are like ordinary canal locks and a vessel can pass through without delay. This canal is operated at a loss, the deficit in 1898 being $245,000 and in 1899 $108,000.

Isthmus of Corinth Canal. Until a ship canal was cut across the Isthmus of Corinth in Greece all the vessels trading between the Mediterranean ports of France, Spain, Italy, and Austria and the ports of Greece, Turkey, Asia Minor, the Black Sea, and the Lower Danube were obliged to go around Cape Matapan. The canal cuts the isthmus in a straight line at its narrowest part, its length being just under four miles, and reaches deep water at both ends about 225 yards from the shore. Its bottom width is 72 feet, width at the sur-

face of the water 77½ feet, depth 26¼ feet. The canal is perfectly straight and the navigator can see through it from one end to the other. The sides of the canal from the bottom to 6½ feet above the surface of the water are lined with concrete blocks to protect the banks from the "wash" of passing vessels. This canal saves for goods from Adriatic ports 185 nautical miles, from Mediterranean ports 95 miles. It was across this isthmus that the Athenians hauled their war galleys three hundred years before Christ. These vessels had three banks of oars and often had crews of more than two hundred men, and are supposed to have been of about 150 tons burden. The canal was open to navigation November 8, 1893.

Canals of France. France has a good system of canals, but combines very strangely some of the latest hydraulic lifts with the most primitive methods of propulsion, for on some of her inland waterways two men are often employed to haul a boat of from 60 to 110 tons burden eleven to sixteen miles per day. A man and a horse harnessed together can haul the same boat about eighteen miles per day.

Military Advantages. Plans for a ship canal from the North Sea to the Mediterranean are very dear to the French heart. Since England holds Gibraltar (the entrance to the Mediterranean) such a canal would be of great strategic value to France in case of war with her, and more especially so if France's "great and good friend" Russia were to complete the proposed ship canal from the Black Sea to the Baltic. Such canals would enable the two countries to concentrate their fleets either in the Mediterranean or the North Sea as occasion might require, and would furnish a safe passage through their own territory for the greater part of the distance.

Suez Canal. However, it is chiefly through her famous engineer, Ferdinand De Lesseps, that France has become famous in canal building. It was he that in 1858 formed the Suez Canal Company

with a capital of $40,000,000. He secured from the Khedive of Egypt, by a gift of a large block of the stock, the desired permission to construct the canal. It was begun in April, 1859, and opened with imposing ceremonies in 1869. Its length was 103 miles, width at bottom 72 feet, depth 26 feet. Its total cost to 1870 was $83,000,000, but of this sum only $58,000,000 was actually expended on the construction, the remainder being devoted to the financiering of the project. Since then the canal has been widened, deepened, and the approaches improved until it has now cost more than $100,000,000. The net tonnage passing through the canal in 1870 was 439,911. In 1880 it had grown to 3,057,421; in 1885, to 6,335,753; and in 1891 to 8,698,777.

The opening of the canal lessened the time necessary for voyages to the East more than one half. By it the sea distance from English ports to ports in India, China, and Australia was decreased more than 4300 nautical miles. It is interesting to note that England at first strongly opposed the building of the canal, but the ways of trade are peculiar, for to-day English capital controls it, having secured the stock of the Khedive. The English occupation of Egypt makes the canal almost exclusively an English waterway.

Tolls and Tonnage. It takes about twenty-two hours for a vessel to pass through the canal, and the tolls are ten francs (about $2.00) per net ton. In the Spanish-American war it cost Camara's fleet thousands of dollars to pass through the canal and make a pretense of reinforcing Manila. Admiral Dewey, on his passage through in the *Olympia* paid as toll $3,516.04. The net tonnage in 1898 was 9,238,603, and the receipts $17,581,200, leaving a surplus over expenditures of $9,757,800. The stock now sells at about five times its par value.

Panama Designs. Having made an assured success of the Suez Canal, De Lesseps turned his attention to the isthmus separating the

continents of North and South America. This at its narrowest part is 31 miles in width. The valley of the Chagres river seemed to offer the most promising passage, as the summit there is only 263 feet above sea level. There are many difficulties to be encountered there not found at Suez. Panama, the city on the Pacific side of the isthmus, has no good harbor, and the tides there rise from twelve to twenty-two feet. Many small rivers descend both coasts and the rainfall is exceedingly heavy. The route chosen was from Chagres on the Atlantic side to New Panama on the Pacific side.

In 1879, upon the invitation of Count Ferdinand De Lesseps, delegates from twenty-four countries to a canal congress assembled in Paris. The congress made De Lesseps president and recommended a sea level canal. Upon the adjournment of the convention the Universal Interoceanic Canal Company was organized by De Lesseps. Subscriptions were received and a route forty-six miles in length with the following dimensions planned. Bottom breadth, 72 to 78 feet; breadth at water level, 92 to 164 feet; depth, 28 to 29½ feet.

Difficulties of the Work. The work was begun but the project met with great difficulties. The water flow of the Chagres river during the rainy season had been underestimated and caused great damage. The climate was hot and a fertile field for the tropical fevers which follow close upon the breaking of the soil. The different layers of earth, shale, rock, etc. were at puzzling angles, and sometimes when a cut was made at the foot of an eminence the whole face of the elevation would seem to protest and come sliding down as fast as cut away. The first estimate of the canal was about $120,000,000. By 1889 $200,000,000 had been expended and the money was exhausted.

Panama Scandal and Bankruptcy. New funds could not be raised and the work ceased. A committee sent to investigate reported that it would cost $243,000,000 to complete the canal. The

company failed and went into the hands of a receiver, who reported in 1890 that he thought it would require $600,000,000 to complete the canal. Meanwhile the French government had ordered an investigation, the gravest financial scandals were uncovered, and several prominent in politics and finance were found guilty and punished, among them De Lesseps' son Charles.

Report of International Commission. In 1894 a new company was formed to complete the Panama canal. It made a minute investigation, requiring the services of 150 engineers for four years. When the committee reported the French government invited an international commission composed of ten engineers of high authority from the United States, Great Britain, Germany, Russia, and France, among them the directors of the Kiel and Manchester canals, to examine the new estimate. The commission organized in 1896 and rendered their decision December 2, 1898. They approved unanimously the plans and estimates of the French committee, which declared the canal to be about two fifths completed and that it would require eight or ten years and about $102,204,000 to fully complete it. The new company has kept about three thousand laborers employed since then. They are able to do only enough to keep the work from deteriorating and prevent the concession from being forfeited while fresh capital is being raised. With abundant capital it is thought that the work could be completed in about eight years.

De Lesseps' Career. The career of this financier, diplomat, and engineer merits some notice. Ferdinand De Lesseps, born in Versailles, 1805, was a cousin of Empress Eugenie, wife of Napoleon III. He had brooded over the Suez canal scheme for years. The emperor and empress approved his plans and this was enough to arouse the prejudice and opposition of England, whose newspapers and engineers pronounced it visionary and impossible. The concession was granted in 1856 and work was begun in 1859. The English

government opposed the project and disputed the legality of the viceroy's action and through its influence the concession was canceled. In spite of all difficulties a small channel was opened August 15, 1865, which was widened and deepened until, November 20, 1869, a tide water canal 100 miles long, which Robert Stephenson and other eminent engineers had to the last declared impossible, was opened with imposing ceremony. De Lesseps was also the promoter of the Isthmus of Corinth canal.

When the Panama scandals were exposed Ferdinand De Lesseps, who knew nothing of the corrupt practices of which his son and the other directors had been guilty, was indicted with the others and received, February 9, 1893, a sentence of five years' imprisonment. He was not in court and was ignorant of the legal proceedings, for he had long suffered from paralytic strokes impairing his vitality and consciousness. The pathetic picture of an old man who had done so much for French honor touched the popular heart, and the knowledge of his disgrace was kept from him. He died near Paris December 7, 1894.

English Canals. The canals of England date back to the time of the Roman occupation, for the Foss Dyke, a canal of Lincolnshire, was originally made by the Romans. The improvement of her internal waterways early received attention, and there are locks on the river Lee more than four centuries old. It is amusing to read of the quarrel between the town of Exeter, situated on the Exe river, and the Earl of Devon, who in 1316 built dams in the river and spoiled it as a waterway.

Manchester. It is to Francis, Duke of Bridgewater, more than to any other person, that England owes the development of her internal waterways. In 1750, owing to the lack of transportation facilities and ignorance concerning use of coal in iron smelting, only 18,000 tons of iron were produced in all England. Four fifths

of its iron was imported from Sweden. Roads which had been fairly good during the Middle Ages broke down under increased traffic. "The new lines of trade lay often along mere country lanes which had never been more than horse tracks, and to drive heavy wains through lanes like these was all but impossible. Much of the woolen trade, therefore, had to be carried on by means of long trains of pack horses, and in most cases the cost of carriage added heavily to the cost of production. In the case of yet heavier goods, such as coal, distribution was almost impracticable save along the greater rivers of any districts accessible from the sea." *

Effect on Freight Rates. The Duke of Bridgewater owned collieries at Worsley whose value depended on Manchester as a market. To bring this coal to market, he planned a canal from his mines to the river Irwell, and James Brindley executed the plans for him. Encouraged by his success, the duke later connected Manchester by canal with Liverpool, 35 miles away. Many vested interests fought this project bitterly, and called the undertaking "the Duke of Bridgewater's folly," but after sixteen years of strenuous opposition the indomitable duke won, although the strife is said to have shortened his life. The gain to transportation was at once apparent. The freight rate between Liverpool and Manchester fell from forty shillings a ton to eight shillings a ton, a new use was found for coal, and England found the richest of all markets, the market of England itself. Although Great Britain has 4700 miles of canals, or more than any other country in the world, a description of the Manchester ship canal will answer the purposes of this article.

Manchester, ambitious for maritime trade, decided in 1884 to build a ship canal 35½ miles long, connecting it with ocean navigation at Liverpool. The latter city had always been the port for Manchester, and, fearing a loss of prestige, would not contribute any

* Green's *Greater History of the English People.*

money to the canal scheme. With characteristic energy Manchester shouldered the burden and after expending $77,000,000 on the scheme opened the canal with appropriate ceremonies January 14, 1894. The canal is 125 feet wide at the bottom and averages more than 170 feet at water level, being wide enough for ships to pass at any point. It is 26 feet deep in any part and rises by means of four sets of locks, from sea level to 60 feet 6 inches at Manchester. The right of way was expensive, many engineering difficulties were encountered, and the Duke of Bridgewater's canal lay right across its path. This canal, that threatened to be such an obstacle, now has its boats taken up in a water cradle, lifted over the Manchester canal and deposited on the other side. All structures crossing the canal have been placed 75 feet overhead to afford room for the rigging of passing ships.

Now comes one of the strange freaks of trade, for Manchester, contrary to expectation, is not a great seaport town. The local shipping between it and Liverpool has increased, but the tolls on the canal average only $175,000 per year, or less than enough to pay operating expenses and interest on the debt incurred, so the people of Manchester are taxed to feed the "White Elephant" while Liverpool reaps great benefit from one of the great achievements of modern engineering,— a canal which she feared so much when first planned that she would not contribute to its construction. May not the Manchester ship canal hold a lesson for New York city?

Canadian Canals.* The history of Canadian canals is closely linked with the political history of the country. The first constructed were small barge canals around the rapids of the St. Lawrence between Lakes St. Louis and St. Francis. These were constructed by the British government during the Revolutionary War to afford passage for military supplies to the Great Lakes,

* From data furnished by Prof. I. G. G. Kerry of McGill University.

The first lock at Sault Ste. Marie, where is now located the busiest canal in the world, was built in 1798 by a Montreal firm for use in the fur trade. On both the American and Canadian sides are locks free of tolls to vessels of both nationalities. The Canadian Pacific and the Grand Trunk railroads pass for a short distance through the United States and in exchange for the privilege of shipping goods "in bond" through on these lines, American vessels and Canadian vessels on the St. Lawrence canals are given equal rights.

After the war with the United States (1812–15) Canada began improvements on the canals, and in 1834 a 5-foot waterway was opened from the Upper Lakes to the sea.

The Welland canal, between Lakes Erie and Ontario, was a private enterprise heavily subsidized by both the Canadian and the home governments.

"The Rideau canal was built entirely at the expense of the British government and its route was chosen in order to be as far distant as possible from the American border. It was primarily a military work." It established water communication between Ottawa and Kingston and is to-day the largest of the Canadian canals (132¾ miles) but it has no towpath and only 8½ miles of it is canal proper, the waterway being obtained by building large dams, forming ponds above them.

After the union of Upper and Lower Canada in 1841 improvements in canal construction resulted in giving by 1849 a 9-foot waterway from Lake Huron to the sea. After the Confederation the government undertook the construction of a 14-foot waterway from Lake Superior to the sea and the last link of this, the Soulanges canal, 14 miles in length, was completed in 1900. The locks of this canal are 270 feet long, 45 feet wide, with a minimum of 14 feet of water.

"Generally speaking, canal construction in Canada may be said to be entirely governmental, and each improvement has followed after a great political crisis, as the need of better transportation facilities to knit the country together was realized." Although superior to the Erie canal it may be said that they have never developed the traffic that was expected.

The St. Lawrence canals only are now of great importance. They afford 1274 miles of navigation in Canadian waters, extending from Montreal on the St. Lawrence to Port Arthur on the northern shore of Lake Superior. On this route there are 71 miles of canal proper with 47 locks, having an aggregate lift of 551 feet. The locks will not accommodate vessels more than 225 feet long and of about 1800 tons capacity, and should be increased in length at least 50 per cent. They must be closed through the winter from December 1st to May 1st.

Heavy Tonnage of the Welland. In 1897 the vegetable food tonnage passing through the Welland canal exceeded for the first time in its history that of the Erie canal. The grain rates by rail from Chicago to Montreal vary from 3½ cents to 4½ cents per bushel. Canal tolls are 10 cents a ton on grain and 20 cents a ton on coal east bound. Wharfage at Montreal is 6 cents a ton and elevator charges ½ cent a bushel.

From the Great Lakes to England Direct. Canals do not furnish Canada adequate transportation on account of the long winter freezing not only the canals but the St. Lawrence river. Up to June 30, 1898, $72,405,401 had been spent in canal construction, and $15,067,096 on repairs, maintenance, and operation. The total revenue received amounted to $11,710,240. The canal system exclusive of interest on capital was operated for the year ending June, 1898, at a loss of $217,093. November, 1900, the steamer *Monk Haven* left Carnegie's lake port Conneaut, with a cargo of steel billets, for

Avonmouth, England, by way of the Lakes and the Welland canal. She is the first vessel to carry steel from the Great Lakes directly to England.

The Shifting Course of Trade. The courses of grain shipments are changing somewhat. November 17, 1900, the first cargo of western grain to be shipped by the new Canadian route was taken from the Great Northern railway elevator at Quebec. That elevator has a capacity of 1,000,000 bushels, and American capital is largely represented in its construction. Grain from the Northwest shipped by this route is brought from Duluth by steamer through Parry sound to an elevator built at the edge of deep water and having a capacity of 1,250,000 bushels. It takes the grain directly from the vessel and loads it on to the cars running over the Canadian Atlantic road via Ottawa to Quebec. This route shortens the distance between Duluth and Liverpool 800 miles. Trains at Quebec run directly into the elevator there, and steamships go alongside where they have 40 feet of water. Grain is thus handled at a minimum cost, for the largest ships can be easily handled at Quebec. Somehow sea captains do not seem to fancy the narrow tortuous route between Quebec and Montreal, and the latter city may find the experience of Manchester repeated in her own case.

The Chicago drainage canal is one of the triumphs of modern engineering. Chicago derives her water supply from Lake Michigan, having built a tunnel out under the lake with an "intake" a considerable distance from the shore. However, the amount of sewage discharged into the lake was so great that eventually it polluted the water supply. Something had to be done, and Chicago, with characteristic daring and enterprise, cut a canal connecting Lake Michigan with the Illinois river, 34 miles away. Into this the drainage of the city was turned and water admitted to dilute it enough so it would not be a menace to the health of the country through which it

passed. The whole is kept constantly in motion until discharged in the river. This disposal of the city's drainage frees the water supply in Lake Michigan from any danger of pollution.

A Water Route, Chicago to New Orleans. Geologists say that before the glacial period Lake Michigan had a southern outlet. Certain it is that at high water its only barrier at Chicago is about four feet of rock and two feet of gravel, and a ship canal connecting Chicago with the Mississippi river has been many times proposed. The construction of the Chicago canal was begun September 3, 1892, and an open channel 22 feet deep and from 162 feet to 202 feet wide was cut without locks, affording a continuous current its whole length. The Des Plaines river was taken out of its course, a new bed thirteen miles long built for it, and the old bed utilized for the canal. The construction involved the removal of about 40,000,000 cubic yards of material. The right of way alone cost about $2,000,000, and the total expense with interest charges January 1, 1900, amounted to nearly $34,000,000. The canal affords passage for ships of about twenty feet draft. Perhaps no very distant future may see improvements in the Illinois and Mississippi rivers that will give a route at least twelve or fourteen feet deep, affording direct water communication between Chicago and New Orleans, to the great advantage of both cities.

The busiest canal in the world is one of which probably the least is heard. It is the Sault Ste. Marie, connecting Lake Superior with Lake Michigan, and it carries more than double the tonnage of the Suez canal. It is closed by ice during part of the year. For the seven months ending October, 1900, there had passed through 28,174 passengers and 23,090,166 tons of freight. It is significant that of this four fifths is east bound freight, consisting chiefly of wheat, other grain, iron ore, and flour. Mulhall estimated the wheat crop of the United States in 1895 at 490,000,000 bushels. In

the seven months just named there passed through this canal, of which half the people on the American continent have never heard, 33,000,000 bushels of wheat.

The first canal in the United States was built at South Hadley, Mass., in 1793, to enable boats to get around the falls of the Connecticut river at that point. On this canal a boat ran into a water-tight box, having gates at each end, and floated on the water in the box, while the whole affair was hauled by cables up or down an inclined way; arriving at the other level the gates opened and the boat proceeded on its way.

The Erie canal has had a greater effect on the political history of a continent and the movement of traffic and population than any similar work in the world. Before it was built the only means of transportation between the East and West was by horse and wagon. The completion of the canal realized the dreams of Washington, emphasized the difference between *no* transportation and *good* transportation, and exerted a marvelous effect in developing the country and building up its commerce. It was begun in 1791 as a private enterprise but was completed as a state work and opened November 4, 1825. It was 4 feet deep, 40 feet wide on the surface, and could float boats of 80 tons capacity, was 352 miles in length and connected Lake Erie with the Hudson river. Its eastern end touches tide water in the Hudson but its western end is 573 feet above sea level. The water of Lake Erie does not enter the Hudson because of two summits which intervene. This canal carried across the country, rising and falling with the surface of the land, is built in level sections, the water in each level being kept in place by gates across it, termed *locks*.

In the first canals built by man a portage had to be made in changing from one level to another, until a means was devised for moving loaded boats. The sluice, the first of these inventions, con-

From Harper's Round Table.

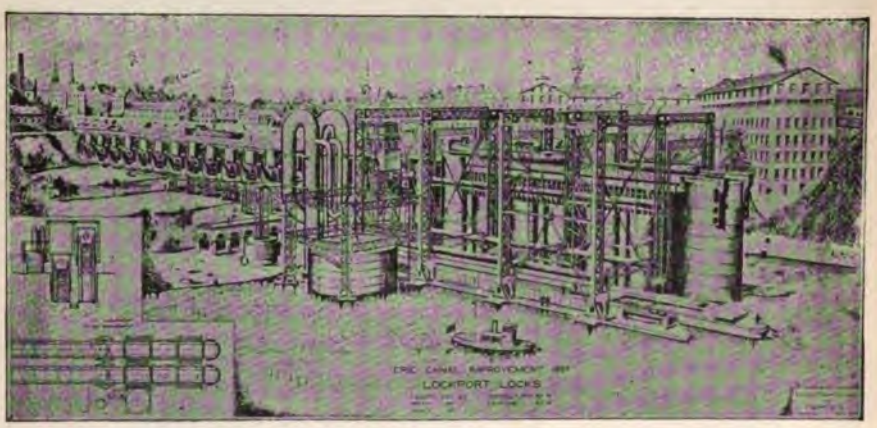
THE NIAGARA LOCKS OF THE MARITIME CANAL COMPANY OF NORTH AMERICA.

Showing the contrast between the Dutton Pneumatic and old fashioned locks.

sisted of an inclined way down which the water ran and the boat was allowed to slide down with the water or dragged up against it. On the Grand canal in China boats are transferred from one level to another by hauling them over such an inclined plane.

The hydraulic lock, said to have been invented by Leonardo Da Vinci about 1481, exerted a profound influence on commerce and made the canal system really efficient. It consists of a huge box of masonry connected at different levels, closed at the ends by water-tight gates, with valves in them to allow the ingress and exit of water. To pass a boat downward the lower gates are closed, the upper gates opened, and the lock appears as a continuation of the upper level; the upper gates are then closed, the water let out through the valves in the lower gates and, when the water in the lock falls until it is even with the lower level, the lower gates are opened and the boat goes on its way. To pass a boat upward the process is reversed. This method was used for 500 years until a lock built of steel and operated by compressed air was invented by Chauncey N. Dutton of New York, who in 1891 patented the Dutton Pneumatic Lock, a ship elevator operating as a pneumatic balance. In it thin walls of steel take the place of heavy walls of masonry and frictionless mobile air is used instead of ponderous and slow moving water. The locks operate floating on air and moving up and down, balancing one another like the pans of a scale. The operation really is weighing, for the motion is caused by an excess of water in the elevated lock which depresses it and at the same time elevates the lighter one. The principle can be understood by immersing a tumbler mouth downward in water. The air within the tumbler cannot escape because it is lighter than water. If we take two tumblers and connect the air space in each by a tube and prevent them from capsizing, we have a model of the pneumatic lock, and if a weight is placed on one and it is depressed, the air rushes through the connecting tube and raises the other tumbler.

New York state adopted these locks at Lockport, where one lift of 55½ feet replaces 5 masonry locks and gains two hours of time for a fleet of boats. The most famous is at Cohoes, where one lift of 140 feet will replace 16 locks, and save one half day's time and ⅛ of a cent per bushel on the cost of moving grain. The channel in the Mohawk river and the canal 140 feet above will be connected by a gated approach in which are two huge pits 175 feet deep, 50 feet wide, and 320 feet long.



THE DUTTON PNEUMATIC LOCK.

Each pit contains a gigantic steel box or caisson having no bottom and bearing on its top a huge water-tight tank long enough to hold five canal boats. Each end of the tank is fitted with water-tight gates through which the boats may pass, one end of each tank making perfect alignment and a water-tight joint with one of the mouths of the canal. The sides of the boxes are so long that they extend down into the pit a considerable distance below the water even when the lock is elevated. It is plain that in each lock air will be imprisoned like air underneath inverted tumblers. Because its center of gravity is very high such a lock tends to tip over, and air being elastic and

affected by every change in temperature the lock cannot be held stationary on contained air. Mr. Dutton's ingenuity converted the elasticity of the air from a hindrance into a help and devised a means of giving locks a motion that should be parallel and practically frictionless.

The elasticity of the air was utilized by simply floating the low-

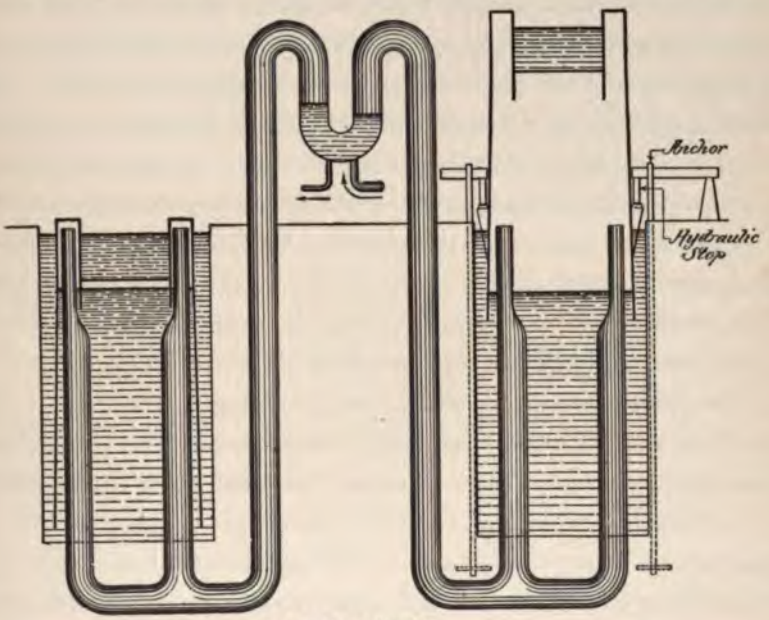


DIAGRAM SHOWING
AIR CONDUIT AND VALVE
OF THE DUTTON LOCK.

ered lock and making it displace exactly its own weight of water and by causing it to displace *more* than its own weight of water when elevated, so that it would be held firmly in position against anchors. The lock might be carrying a load of thousands of tons either at one end or one side and, if not supported, would tip over. To avoid this the locks move up and down between strong steel towers on each

side, which prevents them from tipping over, and they are made to move parallel by long horizontal shafts carrying toothed pinions that fit into toothed racks on the sides of the lock and similar racks on those of the towers. The shafts hang on the teeth of the pinions without other bearings and, as the locks move up and down, the shafts roll and the pinions on them fit into the racks on the towers and locks and the latter are held horizontal, no matter how unevenly loaded. Connecting each lock must be a tube with an air-tight valve of large size. That the locks of Cohoes might move with a speed of a foot a second, an air-tight tube 13 feet in diameter was necessary to connect them. To hold the locks in any desired position a valve in this air pipe was necessary to prevent the free discharge of the air. A mechanical valve was not feasible but the familiar water trap, used in plumbing, solved the difficulty as is shown in the diagram of "Air Conduit and Valve." The long shafts holding the locks level show clearly in the picture of the Lockport locks.

The locks operate in pairs, one balancing the other. If side by side they are said to be "parallel," but they may be set end to end, when they are said to be "tandem," the lift being divided between two or more, set one in advance of the other on different levels, this arrangement being the cheaper. The displacement of water is varied automatically by the lock according to its position, when lowest displacing exactly its own weight and floating like a vessel. When elevated it displaces more than its weight so that it is thrust up against its anchors and held firmly to render its working safe. The construction of the locks may vary with the need of the soil, a caisson working in one huge pit, where the formation is hard or in a series of wells, where the soil will not sustain itself. The compressed air used in operating the caissons is not discharged into the atmosphere, so there is no waste and very little leakage, an air compressor keeping up the supply of what is unavoidably lost. The system

operates as follows: Suppose one lock to be elevated and connected with the upper level, the other to be floating in the lower level with its gates open so as to be a part of it. Boats in the upper level to be locked down enter the elevated lock, those to be locked up enter the lower lock. At such times the locks are held firmly in place because the water in the "U" curved tube traps the air so that none can pass from one lock to the other. The air under the elevated lock is at maximum pressure and holds the lock firmly against its anchors. Suppose 10 feet of water to be within the tank of the lowered lock and 11 feet of water within the tank of the upper lock. Then the gates are closed, the joint broken between the elevated lock and the corresponding mouth in the upper level, and the "U" valve is untrapped, so that air can flow from the air chamber of one lock to the other. Such flow is from the place of greater pressure, *i. e.*, the air chamber of the elevated lock, to the place of lower pressure, *i. e.*, the air chamber of the lower lock, which will ascend while the other descends, just as occurs in a scale when weighing. The lower lock will move up until it is stopped by its anchors and the other will descend and come to rest, in equilibrium, in the lower level. The "U" valve is now closed by trapping it with water and the elevated lock is firmly supported. The gates can be opened and the boats just locked go their way. Thereupon, the newly lowered lock adjusts itself automatically in the water so as to lose the excess draft with which it descended; and the newly elevated lock is adjusted relatively to the water surface in the upper level with which it communicates, so as to take in an additional draft of water, say 1 foot, and become heavier than and ready to raise, by its own subsequent descent, the lock just now depressed and lightened as aforesaid.

The reduction in the cost of transporting wheat from Chicago to New York from 1870 to 1893 made a difference of 20 cents a

bushel in the price of wheat at the latter city. A ton of flour can now be carried from San Francisco to Boston for less than it cost one hundred years ago to carry a barrel of salt from Syracuse to Albany.

Every improvement in transportation has rendered the obtaining of a livelihood easier. Steam has brought Manitoba nearer to London to-day than New York was to Boston a hundred years ago. In days when communication by sea afforded almost the only means of transportation, nations with a broken seacoast, affording numerous harbors, enjoyed many advantages and ranked highest in intelligence. Railroads and means of communication have changed the whole world. Transportation affects every person in the land, as it affects the price of what is eaten, worn, used, the cost, speed, comfort, and convenience of travel, social relations, and general intelligence. It carries raw materials to the manufacturer and finished products from the manufacturer to the consumer. It affects the number of persons employed, the wages paid them, and these in turn react on other lines of occupation. It enables the laborer to go to points where he is at a premium and to leave when work becomes slack, thus benefiting himself and the fellow laborers he leaves behind; quite a marked contrast to the days when he could travel only by tramping across the country with a bundle on a stick slung over his shoulder. Quick and rapid means of communication and transportation helps reconcile people to living farther from their loved ones. Heartrending as was the Galveston disaster the imagination cannot picture the horrors that would have followed had the sufferers been deprived of the assistance afforded by the telegraph, the railroad, and the steamship.

Much may be said in defense of daring efforts of the steamship and the railroad companies to break records. Days and weeks are of little consideration to a savage, but every moment saved to an intel-

ligent nation contributes to its material wealth, and the hours of an Edison may affect the well-being of a nation.

Relation of Transportation to War. Transportation is a potent, frequently the decisive, factor in all military campaigns. Whatever the transcontinental lines may have cost the United States, and whatever scandals may have been connected with them, he would have been a bold man who dared deny that their military value during the war with Spain or the crisis at Peking had been worth all they have cost. Quick and easy means of communication and transportation make the people of the world better acquainted with each other, more tolerant and broad minded. Had the North and the South fifty years ago been knit by railroads, telegraph lines, and commercial interests as closely as to-day, a terrible fratricidal strife might have been averted.

Railroads and Morality. Railroad and steamship systems help to raise the standard of morality. No steamship company is likely to employ as captain or navigating officer a man known to be addicted to the use of intoxicants. The train dispatcher who has thousands of lives and millions of dollars worth of property intrusted to his charge must be a man of good habits and steady nerves. A prominent Western railroad has recently forbidden the use of tobacco by a portion of its employees when on duty. A man known to be given to betting or gambling is not considered the safest person in the world to handle the money at the ticket office.

Great Saving by Means of Railroads. Mulhall stated in 1895 that the merchandise carried from day to day on American railroads was equal to the total weight of the entire population. It costs about thirty cents a mile to haul a ton of freight by horses and wagons over the average country road at all seasons of the year. During the year ending June 30, 1899, the average freight carried by the railroads of the United States over one mile of track was 659,560

tons, at an average price of .724 of a cent per ton mile. In other words, each mile of railroad saved to the nation, over the expense of hauling by horses, more than $190,000. The railroads of the United States carry more freight than those of any other country, but even in Germany it is estimated that each mile of railroad causes a yearly saving of about $31,000 to the public.

Government control of railroads is often advocated. It is urged that such control would prevent the construction of all unnecessary lines and the destructive effects of railroad wars. True it is that about two thirds of the railroads of the United States are unable to pay dividends, and such roads are a loss to their investors. But the United States has never to any great extent subsidized its railroad and steamship lines and other nations do this heavily. Perhaps the loss to investors is no greater than the subsidies other nations are in the habit of paying, and if that is true, a small group of investors have borne the burden of the road, instead of its being carried as a general tax upon the people at large in the form of a subsidy. It has yet to be conclusively demonstrated that government control of railroads is desirable. Canada began the construction of the Canadian Pacific railroad as a public work, but was later glad to turn it over to private companies, and provincial and municipal aid paid about 20 per cent. of the cost of its construction. The success of government administration varies with different countries. The administration of some has been about as bad as it could be. Of those that have tried it Germany seems the only one that is fairly successful, and Germany as a nation is peculiarly well adapted to exercise governmental supervision. Yet even there, where the results in some respects are extremely good, the roads as a whole are not equal to anything like the American standard of efficiency, speed, amount of train service, or rapidity of development. In spite of all the "water" that is popularly supposed to exist in the stock of Ameri-

can railroads their capitalization is less per mile than those of Europe.

It is by no means certain, and perhaps not probable, that governmental selection would secure better men for railroad management than are now secured, for favoritism plays little part in the strenuous competition of modern companies, and it is pretty certain that any man who attains and maintains his position at the head of a great corporation has at least some of the qualities of mind required, although his moral fitness may not be so certain.

Relief for the Terrible Congestion of the City. Rapid and cheap transportation will be one of the most powerful factors in overcoming the terrible evil of the crowded tenement house system of large cities. Some portions of New York city are the most thickly populated in the world. Numerous tenement house districts average from 900 to 1000 people per acre, and one block of tenements, bounded by 61st and 62d Streets and 10th and 11th Avenues, is said to contain 2639 rooms, more than one half of which have no opening into the outer air. An investigating committee reported that in many cases there were from ten to twelve persons living in one room. Such a condition of affairs is not only prejudicial to the morals of the community but a menace to the general health, for contagious diseases breaking out in such locations spread with frightful rapidity and virulence. It is not to be understood that with rapid transit such people would go outside the city to live. Strange to say, they are the very last to move, but some not so low down in the scale would go outside to better quarters, leaving a chance for others to move into the places vacated and so help relieve the pressure on the "submerged" districts.

Effect on Immigration and Settlement. The development of steamship and railroad lines has alone made possible the settlement of a large portion of the American continent. British Columbia rec-

ognized the importance of communication with the outside world when she made her coming into the Confederation dependent upon the building of a railroad. To stimulate the development of her vast fields in Siberia, Russia is offering to carry settlers there 4000 miles for $3.62; while to encourage the development of its western country, the United States so long as its government land lasted, gave farms to actual settlers. It is estimated that prior to 1820, less than 250,000 emigrants came to the United States. For the ten years ending 1830, the average of emigration was 14,343 per year. From 1830 to 1840 transportation systems began to feel the stimulus of the railroad and the steamship, and the length of time and cost of passage was so greatly reduced for that decade that the average was 59,912 per year. As rates cheapened it bounded to 171,325 for 1840 to 1850; 259,821 from 1850 to 1860; 231,482, 1860 to 1870, the Civil War period; 281,229, 1870 to 1880; 524,661, 1880 to 1890. The emigrants have developed the farm lands of the West, built canals and railroads, brought coal and iron from the mines, and by such services added to the material wealth and prosperity of the country.

The Dominion of Canada gives much attention to the subject of colonization, and when in 1870 the great Northwest, until then the domain of the Hudson Bay Company, passed into the possession of the Canadian government the colonization of the great tract was deemed of prime importance and fostered so carefully that within ten years the population has doubled. The government owns most of the unoccupied land there, though the Hudson Bay Company retained one twentieth at the time of the transfer, and the Canadian Pacific railroad received 25,000,000 acres as one of its bonuses. One of the best proofs of the dependence of the country upon the railroad is that all along the line of any new road its land is now taken up by settlers ahead of the construction of the road.

An emigrant from Europe taking steerage passage can be landed in Montreal for from $25 to $28. From there he can go in a colonists' sleeping car to Winnipeg for $22.50 and have his freight taken with him at special rate or be given a pass if he brings live stock. As a further incentive the Canadian Pacific railroad will refund his fare if he buys land of them. At harvest time in the Northwest, harvest hands can go from Montreal to Winnipeg and return for $28, a trip of 1424 miles each way, and each season thousands of men from Ontario and Quebec make that trip and assist in gathering the wheat crop.

Many picturesque features appear in connection with the history of Canadian colonization. Longfellow has immortalized one, and Charles G. D. Roberts, in his "Sister to Evangeline," has interestingly depicted another. The United Empire Loyalists, forced by the result of the Revolution to leave the United States, present a striking picture and during the period when slavery existed in the Great Republic a colored refugee who often traveled alone by night with only the pole star as a guide, found in Canada a haven of refuge. One of the most interesting incidents in the history of these movements is that of the Mennonites who came from Russia in 1874 to escape religious persecution at home. They borrowed $96,400 from the government for expenses and were so industrious and well established that by 1892 they had paid it all back, principal and interest.

The great Klondike stampede in 1897–98 took place in spite of all the difficulties of transportation, but resulted in the building of the White Pass and Yukon River railroad, from Skagway to the White Horse Rapids, a distance of 112 miles. In going a distance of only 21 miles this road makes a climb of 2825 feet and reaches the summit of the White Pass, a performance that is justly considered one of the noteworthy feats of engineering.

In view of what the railroads and canals have done for Canada it is very interesting to note that in 1790 Adam Lymburner, sent as a delegate by the Canadian people to England, stated that the lands of western Ontario would never be settled because the Niagara Falls offered an insurmountable obstacle to their commercial development.

TRAFFIC ON THE CANAL.

ELECTRICITY.

Its Relation to Light — Its Mystery — Loadstone — Leyden Jar — Franklin; his Kite and Lightning Rod — Galvani — Volta — Frictional Electricity — Static Electricity — Electricity of Chemical Action — Electricity of Heat — Electricity of Magnetism — Mariner's Compass — Discoverers and Discoveries That Made Possible the Dynamo — Electric Motors — Measures of Electricity: Ampère, Ohm, Watt, Volt — Electric Railroads — Arc Light — Search Light — Incandescent Lamp and its Inventors — Electric Heat — Electric Welding — Economy of the Firefly — Electric Furnace — Carborundum — Aluminum — Calcium Carbide — Electroplating — How Storage Batteries Save Power — Practical Applications of Electricity.

THOMAS A. EDISON.

THOUSANDS of years ago it was known that if a piece of amber were rubbed it would attract light substances, and for want of a better explanation of the mystery it was considered to have a "soul."

Even the luxuriant imagination of the Orient could conceive of nothing more marvelous than the wonders performed by the genie that Aladdin summoned by rubbing his lamp, but the actual achievements of the scientists have exceeded the wildest flights of the imagination of the Oriental story-teller, for the magic of the genie of the lamp pales into insignificance beside the work performed by the "soul" of the amber. The latter with a strength that is tireless and a speed that is instantaneous carries messages over the land and under the sea, furnishes a light rivaling that of the sun and a heat that renders that of a coal furnace cool by comparison, looks through materials opaque to the human eye and pictures substances lying within, records the inflections of the human voice and reproduces them at the pleasure of the master it serves.

Space will permit but the briefest review of this invisible force, our acquaintance with which is limited to a few of its manifestations. The subject of electricity has been needlessly surrounded with mystery, and it is unfortunate that many writers in attempting to define it have employed obscure language for the purpose of concealing a lack of knowledge which they were not honest enough to admit.

A study of the phenomena of light and color practically compels a belief in the existence of an "ether" vastly more subtle than air, filling all space, and whose vibrations convey the sensation of light. The investigations of numerous scientists, but more especially those of Faraday, Maxwell, and Hertz, have shown that light and electricity possess many properties in common, and Maxwell has maintained that "light is a purely electrical phenomenon." He has assumed that the ether of light is identical with the ether of electricity and that waves of each travel with about the same velocity, 186,000 miles per second. The investigations of Hertz and many others are continually piling up evidence in support of Maxwell's theory. For Hertz has actually found the waves that Maxwell assumed to be present and has proved that if the right materials are used to produce the effects they will obey the laws of the waves of light governing reflection, refraction, and interference. It was but a step from the discovery of the Hertzian waves to the wireless telegraphy of Marconi. For all the purposes of this sketch electricity will be considered as energy which may appear in many guises.

Probably no other branch of science employs expressions with meanings so contradictory to the principles they are used to describe. The terms fluid, current, flow, charge, discharge, and numerous others give a clew to the various ideas once held concerning this strange force. The work of some of the pioneers in electrical discovery will be briefly reviewed and some of the applications of the force for commercial purposes described.

The Earliest Students of Electricity. Thales of Miletus, writing 600 B.C., mentions the magnetic property of amber, and Theophrastus, 300 B.C., discovered the same property in the tourmaline, but it was not until Dr. Gilbert, physician to Queen Elizabeth, made extended experiments and published his results that the study of electrical phenomena was systematically developed. It is to Gilbert that we owe the word "electricity," and he can be called the creator of the science of electricity and magnetism. Gilbert made a vast number of experiments and divided all bodies into two classes; those which he could electrify by friction, and those which he could not electrify by friction. To the first class he gave the name "electrics" because they exhibited the peculiar power of amber, taking the Greek name of that substance to designate a phenomenon it showed. Gilbert studied the phenomenon of magnetism at the same time and showed that opposite poles of magnetic needles attract each other. He applied to the neutral middle space the term "equator," which we use to-day. He recorded all his observations and issued them in book form. Improvements in the art of printing made the spread of knowledge easier and the publication of Gilbert's book gave considerable impetus to the study of electricity. Many investigators in different lands gathered new facts concerning the science and deep interest was taken in it, for the age had hardly given up searching for the "philosopher's stone" or the "fountain of youth."

The loadstone, an oxide of iron (Fe_3O_4) known as magnetite, was the original source of magnetism prior to 1820. The derivation of the name has been variously ascribed to the city of Magnesia in Asia Minor, where it is found, or from Magnus, a Greek shepherd on Mount Ida, who found the iron on his crook attracted by a mass of the ore. The loadstone exhibits the quality of magnetism but does not always possess polarity though a piece of steel rubbed upon it will exhibit both magnetism and polarity. It was known to the

ancients and is referred to in the writings of Plato, Euripides, Aristotle, Pliny, and others.

Magnetite is one of the richest of the iron ores, containing about 72.417 per cent. pure iron, and is widely distributed, being substantially the only ore of Sweden and Norway. It constitutes the principal part of the iron ore of Canada and is widely distributed in the United States. The secret of its magnetism is not known but has been ascribed to the effect of the "earth currents" of electricity.

The Leyden jar, invented about 1745, marked the next important gain. It seems certain that at least three and probably more investigators, working independently, made the discovery at about the same time, but it has come to be known by the name of the city where it was most widely used at first. The device usually consists of a glass jar covered with tin foil inside and out to within a short distance of the top. "The mouth is generally closed by a disc of dry wood through which passes a wire to the inner coating. The outer end of the wire usually terminates in a small metallic ball. Its essential feature is that it consists of two conducting surfaces separated by a nonconductor."* The jar is charged by connecting one surface with the earth and the other with an electric current. Sir William Watson added the outer metal coating and was able to draw from his jar a spark sufficient to fire gunpowder and to send an electric current through 12,000 feet of wire. So far as any instruments at that time would show, the velocity of the current through the wire was so high as to appear instantaneous.

Benjamin Franklin about 1747 became interested in electricity through Peter Collinson of the Royal Society of London, who sent him a Leyden jar. Franklin took up the subject with enthusiasm and communicated the results of his work to Mr. Collinson, who read his letters from time to time to the Royal Society. Franklin's

* Mendenhall,

work was not appreciated there, and it was not until Buffon, the celebrated French naturalist, caused a French translation of his letters to be made that their merit was discovered and acknowledged. Franklin's note book of November 7, 1749, says:—

"Electrical fluid agrees with lightning in these particulars: 1. Giving light. 2. Color of the light. 3. Crooked direction. 4. Swift motion. 5. Being conducted by metals. 6. Crack or noise in exploding. 7. Subsisting in water or ice. 8. Rending bodies it passes through. 9. Destroying animals. 10. Melting metals. 11. Firing inflammable substances. 12. Sulphurous smell. The electric fluid is attracted by points,— we do not know whether this property is in lightning. But since they agree in all the particulars wherein we can already compare them, is it not probable they agree likewise in this? *Let the experiment be made.*"*

Franklin's Kite and the Lightning Rod. When his letters were translated the suggestions were acted upon in France and Monsieur D'Alibard appears to have first drawn electricity from the clouds May 10, 1752. Franklin himself performed his famous experiments with the kite in June, 1752, and reported it in a letter dated October 19, 1752. His discovery of the identity of lightning and electricity gave him a wide reputation. He made practical use of his discovery in the lightning rod, which was apparently the first practical application of electricity to the service of man.

Galvani's Experiments. Galvani, professor of anatomy in the Italian College at Bologna, made about 1790 his famous experiments with frogs' legs. It was discovered that the hind legs of frogs, divested of their skins and hung on copper hooks, when swung by the wind and brought in contact with an iron railing contracted as though the muscles were alive. The cause was correctly ascribed to electricity but the strangest ideas prevailed concerning it. Galvani

* Mendenhall.

believed that the electricity was contained within the muscles and nerves of the animal itself and that the metals simply furnished conductors for it, and from this theory arose the term "animal electricity." Many physiologists adopted his idea enthusiastically and fondly dreamed that the mystery of life was about to be solved, and miraculous curative powers were ascribed to it. "Seductive hypotheses were built up which dazzled the mind with words devoid of sense, but vanished as soon as they were tested by reason." "It would seem that without any loss of dignity the present might learn from the mistakes of the past and transmute its foolishness into wisdom. The advertising columns of the periodicals of the present time furnish incontestable evidence, however, of the fact that the people of to-day welcome mystery and deception, if not recognized fraud, just as readily and with as much self-satisfaction as did their ancestors of one hundred years ago." *

Alexander Volta, professor of mathematics in the University of Pavia, Italy, was a contemporary of Galvani and also a student of electricity. He did not accept Galvani's theory and soon produced a battery called after him the voltaic pile. This he described in a letter to Sir Joseph Banks in the year 1800 and produced the most profound sensation in scientific circles. His battery was made of discs of copper and zinc separated by layers of paper or cloth moistened with salt and water, and gave at once a source from which electricity could be obtained at any time when wanted. Prior to this the Leyden jar had been the only means of holding electricity in reserve. The voltaic pile introduced a new era into electrical work, for hitherto electricity had to be studied as it was suddenly discharged and the greatest amount that could be had for such purposes was limited by the capacity of the Leyden jar, while Volta's battery made a continuous current readily available and greatly in-

* Mendenhall.

creased the opportunity for investigation. Volta afterward changed his battery by taking the plates and putting them in cups of water and connecting the tops by wires, giving it the form which it practically retains to-day. With the general use of the voltaic battery electrical progress was rapid and resulted in brilliant discoveries. With it Messrs. Nicholson and Carlisle in 1800 decomposed water, proved it to be composed of the two gases, hydrogen and oxygen, and laid the basis of electro-chemistry.

Sir Humphry Davy (1778–1829) also quickly entered the field with Volta's battery, and by its aid decomposed the fixed alkalies, and discovered numerous new substances, among them potassium. He was considered to have made the most important contributions to science since the time of Isaac Newton, and was knighted for his discoveries.

The arc light was foreshadowed in 1802 by Sir Humphry Davy and successfully demonstrated by him in 1809. Davy's discoveries had aroused such enthusiasm in London that a voltaic battery of 2000 cells containing 128,000 square inches of surface immersed in a mixture of water, nitric and sulphuric acids was put at his disposal. He connected the poles with pieces of charcoal and describes his experiment as follows: "When pieces of charcoal about an inch long and one sixth of an inch in diameter were brought near each other (within the thirtieth or fortieth of an inch), a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness; and, by withdrawing the points from each other, a constant discharge took place through the heated air, in a space equal to at least four inches, producing a most brilliant ascending arch of light, broad and conical in form, in the middle. When any substance was introduced into this arch, it instantly became ignited; platina melted as readily in it as wax in a common candle; quartz, the sapphire, magnesia, lime, all entered into fusion; frag-

ments of diamond and points of charcoal and plumbago rapidly disappeared and seemed to evaporate in it." * Davy had produced an electric light but the large batteries necessary for its production were expensive and irregular in their action, and the lighting problem was forced to wait for Faraday's discovery of electro-magnetic induction and the commercial development of the dynamo. The light was first termed "arch light" because of the brilliant ascending arch of light, and has since come to be known as "arc light."

The kinship of magnetism and electricity was generally recognized prior to 1820, but it remained for Hans Christian Oersted (1777–1851), a Dane, and the son of an apothecary in a little country village of less than 1000 inhabitants, to demonstrate their close relationship. The boy wished to enter the ministry, but somewhat to his disappointment though greatly to the advantage of science, his father put him at work in his pharmacy when twelve years old The mysteries of that simple laboratory had a wonderful fascination for him, and he applied himself with such zeal to obtaining an education that when twenty-two years of age he was given the degree of Doctor of Philosophy by Copenhagen University. He later traveled through Europe and on his return was made professor of physics at his alma mater. Davy, Faraday, Oersted, and many others believed that the forces of nature were much more simple and closely related than their numerous manifestations would at first seem to indicate and that electricity and magnetism would be shown some day to be related.

Oersted's Discovery. In the winter of 1819–20, while Oersted was lecturing before his class, a new idea flashed upon him. He determined to work out the idea before the class and explained to them what he was about to do. Among the apparatus before him was a powerful battery and a suspended magnetic needle. Taking the

* Mendenhall.

poles of the battery he joined them and placed the wire parallel with and over the needle. Instantly the needle swung out of its position and one of the most serviceable discoveries of modern science was revealed. Oersted entered into his experimental work extensively and published the result within a few months. Brilliant and dramatic as had been his discovery it was destined to perform greater marvels in the hands of a contemporary.

Andre Marie Ampere (1775–1836), a French scientist, first learned September 11, 1820, that Oersted had deflected the magnetic needle by a current of electricity. The force of the discovery appealed to him at once, and with astonishing ability he grasped the subject and within a week had demonstrated and reduced to formulas the fundamental laws underlying electro-dynamics. Rarely has so short a time been prolific of discoveries so beneficial to mankind, and Ampère stamped his name indelibly on electrical science, for the unit that measures the current is called after him. Ampère proved that the current could produce magnetic effects without a magnet and that currents flowing through parallel wires in the same direction attracted each other, and finally he reduced it all to mathematics. The work of Oersted and Ampère made possible the telegraph and the telephone. It in fact laid the greater part of the foundation upon which the structure of modern electricity has been reared.

Arago (1786–1853), **a French scientist,** and Sir Humphry Davy each independently discovered in 1820 that a copper wire through which a current of electricity is passing will attract to it iron filings as though it were magnetic. Arago surrounded a glass tube with a coil of wire, put bits of steel inside, passed a current through the coil, and found that the steel inside the tube was magnetized. Oersted had discovered that the current of electricity would influence magnetism but Arago demonstrated by his coil and glass tube that electricity would produce magnetism.

The loadstone was the original source of magnetism prior to 1820. To make a magnet it was necessary that the steel be rubbed upon a loadstone or upon a magnet. Magnetism could be transferred from one to another without loss just as one torch may be lighted by the flame of another. The researches of Oersted, Ampère, and Arago showed that a bar of steel could be made a magnet by passing a current of electricity through it, and "the loadstone as a primary source of magnetism was dethroned and a cell of Volta crowned in its stead."

Sturgeon, an English electrician, a little later substituted soft iron for steel, passed a coil of wire around it, sent an electric current through the coil and found that the iron was a magnet as long as the current of electricity kept up, but that it lasted only while the current was flowing. The soft iron and the electric current gave a more powerful magnet than that of steel, and, more important yet, gave one that could be instantly made magnetic or non-magnetic.

Joseph Henry of Albany, later of Princeton and the Smithsonian Institution, improved upon Sturgeon's magnet by winding it with many coils of wire and produced one weighing sixty pounds that was able to sustain a weight of more than a ton. Sturgeon varnished the iron and wound a naked wire around it, the varnish acting as an insulator. Henry improved the insulation by covering his wire with silk.

The Galvanic multiplier was discovered by Schweigger (born 1830), a German scientist. Working on Oersted's experiment he carried the wire over the needle, bent it, and brought it back under the needle and doubled the effect of the current, and found he could increase its effect each time he made a loop. It followed that a wire through which a very feeble current passed might be bent into enough loops so the magnetic needle would be influenced by it and in this way it became possible to measure currents that before defied

all electrical instruments. Schweigger's discovery applied to the thermo-battery will measure the heat of a star. It took electricity out of the realm of guesswork and conducted it with something like mathematical accuracy. The rapid progress the science has made is in part due to such exactness, for it is evident that even workers with tools would be badly handicapped if compelled to use measures and scales that were crude and inaccurate, then how much more necessary that workers in electrical science employ exact measures of that strange force. It is Galvani's discovery of the "new electricity," Volta's battery that gave the means of generating it, Oersted's instrument that showed its influence upon the magnetic needle, and Faraday's discovery that led to the development of the dynamo, that have rendered possible the greater part of the practical applications of electricity.

Michael Faraday (1791–1867) was the son of a blacksmith and had but limited educational advantages. Apprenticed to a bookbinder at the age of thirteen, he made the most of the opportunities work afforded him, and is said to have become interested in electricity on reading an article upon it in an encyclopedia given him to bind. Seeing the boy's interest in such things, one of his father's customers in 1812 gave him tickets to four lectures on chemistry delivered by Sir Humphry Davy. He made careful notes of the lectures and sent them to Davy with the request that he be given some employment in the Institution. Davy returned the notes and praised his work, but advised him to stick to his bookbinding and promised him the patronage of the Institution, his own, and that of his friends that he could influence. Later, needing assistance, he remembered Faraday and employed him temporarily. It is hardly necessary to say that all Faraday lacked was a chance, and that the temporary employment became permanent, and Davy afterward said that his greatest claim to the gratitude of posterity was that he had

"discovered 'Mike' Faraday." In 1827 he succeeded to Davy's chair of chemistry in the Royal Institution. Electricity had a great fascination for him and after years of study he began on August 29, 1831, a brilliant series of experiments, and by November 24 had collected and presented in a paper read to the Royal Society the general propositions pertaining to "electro-magnetic induction," the basis upon which are built many applications of electricity to man's service. Another important service he performed was proving the doctrine of "definite electro-magnetic decomposition." In his experiments with polarization of light he discovered that light passing through a prism could be cut off or transmitted according as it was acted upon by magnetism, and called this discovery "the magnetism of light." Faraday closed a long and well-spent life as much loved for his manly qualities as he was admired for his scientific attainments.

Since Faraday's death so many improvements in the practical application of electricity have been made that a volume would be needed to simply record the subjects and names of the inventors. The methods of producing it and some of the uses to which it has been applied will now be considered, the telephone and telegraph being treated under the subject of communication. Electricity is commonly produced either by friction, chemical action, heat, or magnetism.

Frictional electricity was the first recognized and is a familiar form of this energy. Any substance when rubbed with a different substance becomes electrified. Ordinary substances may be divided for electrical purposes into three classes: those that are good conductors of electricity, which includes all metals and carbon; those which are neither good conductors nor good insulators, such as water and moist bodies, wood, cotton, paper; last, good insulators, as paraffin, turpentine, silk, resin, sealing wax, India rubber, gutta

percha, ivory, dry wood, dry glass, mica, air at ordinary pressure and temperature. In dry, cold weather the friction of a rubber or tortoise shell comb on the hair will electrify the hair and cause it to cling to the teeth of the comb. If a cat's fur in dry weather be stroked with a dry, warm hand a crackling noise will be noticed and in the dark electric sparks can be plainly seen. In winter a person in slippers can slide rapidly over the carpet, electrify himself, draw a spark from the hair of another person, and on touching a gas jet or any bit of metal draw a spark or perhaps even light the gas. A glass rod rubbed with a piece of silk will become electrified and attract bits of paper, etc. If the rod be brought near a pith ball suspended on a fine thread, the ball will leap forward to meet it and if allowed to touch it will appropriate some of its electricity, be repelled and dart away. If the silk now be substituted for the glass rod, the pith ball will be attracted by that, showing that both the rod and the silk are electrified but that they possess different properties, for here as elsewhere "opposites attract." The condition of the electricity in the rod is said to be positive, that in the silk negative. If cat's fur be substituted for the silk and the rod rubbed with it, the condition of the rod will be negative and of the fur positive. When a storm cloud charged with electricity passes over the earth the opposite kind is induced in the earth beneath it. The cloud and the earth then resemble the inner and outer covering of a Leyden jar, the atmosphere corresponding to the glass of the jar. If the force is sufficiently powerful a flash of lightning will burst through the air and the electrical equilibrium be restored. In most cases the discharges are from one cloud to another unequally charged.

Static electricity, from the Greek word meaning to stand, is that which is stored up or is stationary. Dynamic electricity, from the Greek word meaning power, is that which is in motion and so

possessing power. The electricity with which the cloud is charged is static; that of the lightning's flash, dynamic. In Franklin's experiment with the kite, the electricity of the cloud was static, but when moving in the string was dynamic, and as soon as he transferred it to the Leyden jar it became static again.

If a glass marble or ball is placed on a good insulator and a glass rod or a stick of sealing wax be positively electrified and brought near the ball without touching, it will be found on testing the ball with a bit of pith that the side next the rod is negatively electric and the side from it positively electric, and that when the rod is removed the ball shows no trace of electricity, thus proving that the electricity within the ball was due to the influence of the rod, or was *induced.* It was Faraday's discovery of *induction by an electro-magnet* that rendered commercially possible the utilization of electricity as a motive power where great force is required. Electricity of friction is rather unmanageable and has not been applied practically to any great extent.

The electricity of chemical action was discovered by Volta, the current in his pile being produced by the chemical action of the moisture in the layers of wet paper or wet cloth on the zinc and copper plates they separated. The cell is the most familiar application of Volta's discovery. It usually consists of plates of zinc and copper partly immersed in water containing acid, the plates being separated in the solution but connected at the top by a wire. When so connected electricity is continuously evolved. The mere contact of dry copper and zinc plates electrifies them, but does not produce a continuous current. The copper plate is electrified positively, and the zinc plate electrified negatively. In the days when the fluid theory of electricity prevailed, a positive current was said to flow from the copper through the connecting wire to the zinc. In the cell just described water (H_2O) is separated by the electric current

into hydrogen and oxygen, the gases that form it. The zinc plate is attacked by the oxygen set free, which combines with it and forms oxide of zinc and that plate wastes away. The most of the hydrogen set free gathers in bubbles on the copper plate and retards the action and is said to "polarize the cell."

Various arrangements of cells have been made to counteract this action and of all such the Daniell cell was one of the first and best known. In the Daniell cell the copper is usually placed at the bottom of the jar and surrounded by a solution of sulphate of copper. The zinc, cast in a form to expose much surface, and surrounded by a solution of sulphate of zinc, is placed within a porous earthenware cup, near the top of the cell. The hydrogen that formerly collected on the copper plate now gets out of the way by uniting with the copper sulphate ($CuSO_4$), sets free the pure copper (Cu) in the solution and forms sulphuric acid (H_2SO_4). The pure copper is deposited in a thin film over the copper plate and the chemical action at this pole should be especially noted, for it is the underlying principle in electroplating. At the other pole the oxygen unites with zinc to form zinc oxide (ZnO) and the free sulphuric acid combines with the oxide and forms more zinc sulphate, thus keeping up the efficiency of the cell. The Daniell cell was such a great improvement over its predecessors that the Copley medal was bestowed on its originator in 1837. Of different forms of cells there is almost no end, but the Leclanché, Fuller, De La Rue, Latimer, Clark, and Bunsen are among those best known and most widely employed.

The difference in electrical condition between the poles of a battery, one called positive and the other negative, is termed electromotive force (E. M. F.) or difference of potential. Little is known as to its real cause, but it is accountable for the movement of electricity in the circuit. This is measured by a unit called volt, after Volta, and is the force produced by a single cell made according to certain

standard specifications. Chemical action occurs whenever two different metals in contact are immersed in a liquid which attacks one more readily than it does the other. By increasing the number of cells the difference in potential can be increased and the current made more powerful. Many metals beside copper and zinc are used and "in the following list of materials, when any two in contact are plunged in dilute sulphuric acid, that which is higher in the list becomes the positive plate or negative pole to that which is lower.

"Zinc	Nickel	Sulphur
Cadmium	Bismuth	Gold
Tin	Antimony	Platinum
Lead	Copper	Graphite"
Iron		*

Dry cells can be prepared and the use of liquids avoided by combining the necessary chemicals into thick pastes, and packing the zinc and copper, or zinc and carbon, in them, closing the whole and leaving a vent for the escape of the gas set free by chemical action. Such cells are clean and well adapted for household and medical purposes.

Heat can cause electricity, as was discovered by Professor Seebeck of Berlin about the year 1821. If a bar of antimony and a bar of bismuth be joined at one end, their other ends connected by a wire, and the point of junction be heated to a higher temperature than the rest of the bars, a current of electricity will be set up, passing through the wire from the bismuth to the antimony. This arrangement is called a thermoelectric couple. Other metals instead of bismuth and antimony may be used. In those named in the following list each, reading downward, is positive to the one following.

Bismuth	Lead	Zinc	Phosphorus
Cobalt	Tin	Cadmium	Antimony
Potassium	Copper	Arsenic	Tellurium
Nickel	Platinum	Iron	Selenium
Sodium	Sulphur	Lead	

* John Munro.

The strength of the current in general will increase with the difference in temperature between the point of junction and the free ends of the bars. The electromotive force of such a couple is much smaller than in an ordinary voltaic cell, but the power of the thermo-electric battery can be increased by increasing the couples, the same as by increasing the cells of a chemical battery. For many purposes of experimentation the thermoelectric battery possesses advantages over the chemical. It is cleaner, lighter, and less troublesome to handle. A very sensitive pile can be made, and piles of antimony and bismuth have been made so sensitive that when measured by the galvanometer they indicate the radiation of heat from certain stars. Such are used to measure temperatures where thermometers would not be available, as in deep sea soundings or the interiors of steam cylinders or furnaces. Thermo-batteries change heat directly into electricity without calling in any "third party," but the process can be reversed as well, for if a current of electricity be sent through a thermo-couple from the antimony to the bismuth, the point of junction may be cooled so low that it will freeze water. Thermo-batteries have been used for working telegraphs, lighting houses, and running small electric motors, but, as at present constructed, the cost of operating is in excess of the power derived from them.

The electricity of magnetism is the form now used where great force is required. Its application was first based upon the discoveries of Oersted, Ampère, Faraday, and Joseph Henry, while numerous others have added to the store of knowledge concerning it.

The loadstone with its magnetic and directive properties was known to the ancients, and the Chinese are said to have employed it as early as 26 B.C. to guide their armies over the great plains of China. A statue with an extended arm was carried in a car and was so pivoted that it could easily revolve but, contrary to Western custom, it pointed toward the south instead of the north. About the

beginning of the Christian era, and certainly no later than the fourth or fifth century, Chinese navigators were using a rude mariner's compass. There is hardly any doubt that the compass was introduced into Europe from the East, and the Crusaders are credited with having brought it into France, for it was known to the Arabs centuries before it appeared in Europe.

The first magnetic needles described in European literature belong to the twelfth century. It then was a needle rubbed on a loadstone, put upon a bit of straw, and floated on water, when its point turning to the pole star served to guide travelers. The marvelous instinct of the direction of home possessed by the carrier pigeon is familiar to all and the raven has like instinct. An ancient Norse historian speaks of "Flocke Vildergerser," a Viking king who sailed from Norway to Iceland in 868 and took with him ravens, "for in those days the seaman had no loadstone in the northern countries." With the discovery of the mariner's compass came an enormous increase in human knowledge and the world's commerce. Sailors were no longer compelled to creep timidly along the coast from port to port but could make long voyages out of sight of land.

The power of the magnet was also known to the Egyptians, Greeks, and Romans, and was used in the temples to suspend statues of the gods in mid air or to produce other effects calculated to excite the awe and credulity of the worshipers. It is said that to produce an effect upon his followers, Mohammed's body at his death was inclosed in a metallic coffin and that when carried into a tomb made of magnetic stones the coffin soared aloft and clung to the ceiling, producing a most profound impression on those of his adherents who had not been initiated into the mystery.

The idea that magnetism and electricity were closely related had prevailed some time before Oersted made his famous discovery. Dr. Gilbert, of whom mention has been made, demonstrated that the

whole earth was a great magnet and that in the magnetic needle opposite poles attracted and like poles repelled, and he also noted the variation and dip of the compass.

A bar of steel rubbed upon a loadstone or another magnet becomes magnetic and if suspended the ends will show the north and south poles. If the bar be cut in two, two magnets are produced exhibiting the same property of polarity, and this holds true for the minutest division, until it has come to be believed that in the atom of a magnet one end is positive and the other negative; in other words, that all the atoms composing the magnet are arranged with their positive poles pointing in one direction and their negatives in the other.

A Magnet exerts Influence all about It. If a horseshoe magnet be laid on a piece of paper and iron filings be sprinkled about it they tend to arrange themselves in certain definite curved lines which Faraday termed "lines of magnetic force," and the space within their lines is called the "field."

HORSESHOE MAGNET AND IRON FILINGS.

The close relation of magnetism to electricity early received attention. Oersted showed if a wire be held over a magnetic needle and parallel with it and a current be sent through the wire toward the north, the north pole of the needle would swing to the left or west, and the south pole to the right or east, until, if the current were strong, the needle stood at right angles with the wire. If the electric current were reversed and sent from north to south the needle swung in the opposite direction and thus the direction of the current in a wire could be determined by the compass, and as weak currents deflected the needle but a little the

strength of the current as well as its direction could be measured. Some influence of this sort seems responsible for the action of the mariner's compass. The earth, rotating on its axis, with portions of its surface unequally heated by the sun's rays, has flowing around it magnetic currents and the compass stands approximately at right angles to these. When magnetic storms occur the compass and all electrical instruments are affected and business on telephone and telegraph lines running east and west may be suspended. An unusual display of "sun spots" seems to coincide with such storms. It is generally believed that the outer envelope (photosphere) of the sun is a great body of white hot gas; that some greater force from within blows holes through this envelope, revealing the core of the sun as a dark spot, and that the energy radiated from the core sets up stronger earth currents than that radiated from the outer envelope. As a famous scientist puts it, "In some way, evidently, the sun affects the earth by radiating magnetic lines of force which are cut by the earth's rotation, and so creating currents of electricity. The sun is the field magnet, and the earth is the revolving armature of Nature's great dynamo electric machine." *

The germ of the modern dynamo lay in Faraday's discovery that a current of electricity could be produced in an insulated wire wound around soft iron, by bringing the ends of the wire closely together and rapidly applying and removing a magnet to and from the iron. In 1831 Faraday took a hollow coil of wire, carried the ends from it around a delicate galvanometer and showed by the galvanometer that when a magnet was thrust into the coil a current was induced for an instant in a certain direction, and when the magnet was suddenly withdrawn a current was induced in the opposite direction. As action and reaction are equal, if the magnet was kept stationary and the coil advanced and withdrawn the same effect was produced.

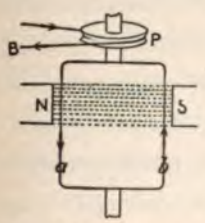
* Elisha Gray.

The line of force about a magnet has been already mentioned. A coil of wire brought within these lines and quickly withdrawn has a current of electricity excited within it, not continuously but only for the instant that it comes within the lines of force or passes outside them. If a wire be placed between the poles of a magnet at right angles to the lines of force, as in the figure shown herewith, and apparently moved from the reader, an electric current will move in the direction of the arrow; if brought toward the reader the current will move in the opposite direction. If the poles of the magnet be reversed the current will also be reversed. This is the principle upon which the dynamo is founded.

THE PRINCIPLE OF THE DYNAMO.

Again, if an electric current be *sent* through the wire in the direction of the arrow the wire will automatically move from the reader in the direction required to produce such a current. If a current be sent in the opposite direction the motion of the wire will be reversed. This is the principle of the electric motor, for the motor is the dynamo reversed.

Suppose a wire to be bent in the form shown in Figure *A* furnished with a pulley, *P*, through which a belt, *B*, connects it with a steam engine, this placed between the poles of a magnet, *N* and *S*. Now if the armature be revolved in the direction shown by arrows on the belt there will be induced in sides *a* and *b* of the armature, currents having the direction shown by the arrows. When side *a* has passed over and is cutting through the lines of force about pole *S* the current will be reversed as will that of side *b* when cutting through the lines of force at pole *N*. As the wire revolves the currents move first in one direction and then the other,



THE PRINCIPLE OF THE MOTOR.

and moving back and forth like this it is called an alternating current. Instead of having the armature of a single wire, as used in our illustration, in actual practice it usually consists of several coils of wire each having a soft iron core and forming electro-magnets all fastened to a shaft made to revolve between the poles of powerful magnets. The electro-magnets in the armature are brought during the revolution close to the poles of the magnets in the field but without touching, and the ends of the wire of each coil in the armature are connected at the hub with separate insulated plates called commutators. The commutators sift out the different currents of electricity and deliver them to flat springs known as brushes, which rest upon the hub and form the electrical connection between the commutators and the wire that is to carry the current away. With reference to the currents produced there are two kinds of dynamos; one the alternating and the other the continuous current. An alternating current has been described and its relation to a dynamo is obvious. The continuous current machine has the commutators and brushes so arranged as to take up all the currents having one direction or polarity and send them through one channel, and all the currents having the opposite direction or polarity through another channel.

In the first dynamos constructed permanent steel magnets were employed, but these were not only expensive but they limited the power of the machine to the strength of the magnet, and made the use of a dynamo impracticable where expense was an item. Later, the magnets were wound with coils of wire through which currents of electricity were passed by voltaic batteries. This increased the strength of the magnet and so the strength of the current induced within the armature, for the stronger the lines of force between the magnetic poles, the stronger the current excited within the armature.

One of the most important improvements was yet to come. About 1855 Hjorth of Copenhagen discarded the voltaic battery and

took the current from the armature, sent it through the coils about the magnets in the field, increased their strength, and by so doing increased the strength of the current they induced in the armature, revolving between the poles. Such a proceeding seems almost like making something out of nothing.

The next great step was to do away altogether with the permanent magnets in the field and to use soft iron cores wound with numerous wrappings of insulated wire through which a current of electricity was passed. Such magnets were far stronger than those having steel cores and the gain in efficiency was marked. It had been thought that permanent magnets were necessary because iron could not be permanently magnetized, and if there were no magnetic force in the field there would be no electricity generated when the armature was revolved, but Siemens discovered that there was enough "residual magnetism" in the iron so that he could dispense with the steel magnets. Such a machine when first started exhibits but slight magnetism and produces a feeble current, but as quickly as the magnets are reinforced by the current produced in the armature they grow stronger and stronger until they reach the point of "saturation" and the machine works at its greatest efficiency. After the electro-magnets in the field have reached the point of "saturation" any additional strength of the current is lost upon them for it does not increase their power.

Where great power is required the electro-magnets in the field are increased in number and may even make a complete circle within which the armature, having as many electro-magnets as can be packed within it, is made to revolve at high speed. After the fundamental principles of electro-dynamics were recognized, Hjorth, Wilde, Siemens, Farmer, Wheatstone, Varley, and Gramme had most to do with their practical application to the dynamo. Of late years Weston, Brush, Edison, Thomson, Houston, Westinghouse and others

have made improvements in its construction and brought it to its present high state of efficiency. Such in brief has been the development of the dynamo, and it has made possible the electric light, the electric street car, electroplating and every branch of applied electricity where any considerable force is required, for though electric heating, lighting, propulsion, etc., were possible with voltaic batteries yet it was at such an expense as to be prohibitive. The principles underlying the application of electricity as a motive power, discovered many years before the perfection of the dynamo, were obliged to wait until the *art* of electricity had caught up with the *science* and some means of producing the force could be devised that would render the practical application of these principles commercially profitable.

One Point must not be Forgotten. The dynamo does not make electricity. It simply transforms into electricity the power required to revolve the armature. This power may be derived from a windmill, a water wheel, or a steam engine. In ordinary practice the dynamo is able to deliver an electric current equivalent to about 90 per cent. of the power furnished by the engine. The best practice approximates 95 per cent., the other 5 per cent. being the toll Nature exacts in the way of friction, losses due to induction, heat, and "leakage."

Electric Motors are about as old as the Dynamo. In 1826 Barlow of Woolrich made a spur wheel something like the escapement of a clock and moved it by electricity. The Abbe Dal Negro of Padua made in 1830 an electric pendulum. In 1828 Professor Joseph Henry devised his powerful electro-magnets, prophesied the use of electricity as a motive power, and in 1831 made and described a crude electric motor. He was followed by Sturgeon, Davenport, Jacobi, Page, and many others, but although the devices of these men were interesting and from them much concerning the princi-

ples of electricity was learned, they were not commercially practicable.

In 1873, at the industrial exhibition at Vienna, several Gramme dynamos were on exhibition. A workman by mistake connected one dynamo to another that was in operation and greatly to his surprise saw the dynamo which he had connected begin to revolve in a contrary direction. The accidental discovery was appreciated. It was found that the Gramme dynamo would work equally well as a motor and a much better understanding of the nature of electric magnetism resulted.

Dynamos and electric motors are now constructed varying as much according to the work required of them as do steam engines and locomotives, and volumes have been written concerning the size of the wire and the manner in which it should be wound, together with other details of construction calculated to give the best results. Space will not permit a technical description. It will be enough for the general reader to know that a steam engine turning a dynamo will produce a current of electricity and that this current of electricity carried to an electric motor differing only in a few details of structure from the dynamo will there produce mechanical motion which can be used to turn machinery.

In every electric motor there are the same two parts as in the dynamo: the armature and the magnetic field. The field is usually produced by a different current from the same source that supplies the motor. By the aid of the dynamo and the electric motor, water power may be utilized by employing it to turn water wheels, the latter turning dynamos. The electric current produced is sent through copper wires to some point where it is to be used and there taken by the electric motor and turned into mechanical force. A waterfall at Lauffen, Germany, as early as 1890, transmitted through a copper wire ¼ inch in diameter 100 horse-power to Frankfort,

about one hundred miles away, with a loss of but 5 per cent. from the wire.

Electric Railroads. With the construction of the Gramme and Siemens dynamos it became possible to operate electric railroads at a profit. At a central power house enormous dynamos turned by huge steam engines send a powerful electric current through the trolley wire, return being made by way of the earth and rails. The current is taken by the car through the trolley pole to an electric motor underneath the floor of the car, which, set in motion by the current, revolves and, being connected with gearing on the axle of the car wheels, propels the car at a speed varying with the strength of the current. The speed of the motor is regulated by changing the electrical pressure at the brushes of the armature. Almost any desired speed can be attained, 130 miles per hour having been reached in experiments, for the motor revolving continuously in one direction has an advantage over the steam engine with its reciprocating parts which must be stopped and started many times a second.

Measures of Electricity. What in electricity corresponds to pressure in steam and water is measured by a unit called "volt," from Volta, the inventor of the voltaic battery. A volt is the power or electromotive force of one cell of a battery made according to standard specifications, just the same as a cord of wood is a pile having a certain length and height.

Electricity passes through some metals easier than others. Silver is the best conductor and the other metals follow in the order named: copper, zinc, platinum, iron, German silver, mercury; copper being a pretty good conductor while iron offers nearly seven times as much resistance as silver, in order to get as much electricity through a copper wire as through a silver wire of the same size, the pressure must be increased. The unit of measure for the resistance offered by the wire is the "ohm," so named after G. S. Ohm, a physicist

of Bavaria, who discovered the so-called Ohm's law, which is that the strength of the current varies directly as the electromotive force and inversely as the resistance. An ohm is the resistance which a column of mercury one millimeter square and 106.3 centimeters long offers to a current of electricity. The resistance offered by a mile of ordinary telegraph wire is about thirteen ohms.

The ampere is the unit that measures the strength of the current in the wire and is named after the celebrated French electrician, A. M. Ampère. It is the current from a battery having one *volt* electromotive force, sent through a wire having one *ohm* of resistance, and such a current is equivalent in mechanical energy to one *watt*, and 746 watts are equal to one horse-power. The watt is named after James Watt of steam engine fame.

The transformer is a device by which alternating currents of electricity can be changed from one pressure or voltage to a different one. The electric currents as sent from power plants frequently range from 2000 to 2500 volts. Such a pressure would be dangerous to take inside a dwelling, for if the insulation were faulty fires would start and the presence of a wire having such a voltage would be a constant menace to life, for a shock of 1000 volts would be serious if not fatal to a human being. The alternating currents used for ordinary street lamps usually range from 1000 to 1500 volts and this is a higher pressure than is necessary in the light proper, for arc lights usually run with from 50 to 100 volts each. The change is effected by the box-shaped apparatus frequently seen on electric light poles. These are called transformers and by them a current at a high pressure can be turned into a low pressure, in which case it is a "step-down" transformer, or a low pressure may be changed into a high pressure, in which case it is a "step-up" transformer. If a current of water be sent under heavy pressure through a small pipe and discharged into a tight box having as an outlet a much larger

pipe it is plain that while the large pipe will discharge in a given length of time the same amount of water as the small one, it will do so at much less pressure. Such an arrangement of the pipes and box might be called a "step-down" transformer. If the current of water were sent through the large pipe it is plain that it would be discharged through the small pipe at much greater velocity and such an arrangement would be a "step-up" transformer. In the power plant at Niagara the current as it comes from the dynamos is about 2200 volts. To transmit the power to Buffalo economically it is advisable to send it under heavy pressure, as the "resistance" and loss of force is much less proportionately, so the current is "stepped-up" to about 10,000 volts, taken to Buffalo, and "stepped-down" to the voltage required for that place.

The transformer itself is but a modification of the "induction coil" with the core usually made of a bundle of rather coarse, soft iron wires, for these wires magnetize and demagnetize more rapidly than would a solid core. Around this core, called the primary coil, is wound a secondary coil of *fine* wire. Now, if a powerful alternating current be sent through the fine wire a current of less voltage but more quantity will be induced in the coarse wire. This is the "step-down" arrangement. If the current is sent through the coarse wire it is "stepped-up" and goes through the smaller wire at a greater pressure.

The arc light was profitably employed as soon as the dynamo had been developed to where it could produce the necessary electricity at moderate expense. Sir Humphry Davy noted as early as 1802 that when a current of electricity was sent through two bits of carbon it heated them to white heat. In 1809 he produced a magnificent 4-inch arc light and exhibited it to the public in 1810, but the energy when furnished by a voltaic battery was very expensive and such batteries are more likely to get out of order than steam engines and

dynamos. Even after the dynamo was ready the fears and prejudices of the public had to be removed and insurance companies shown that new methods of lighting did not involve more danger than the methods in use.

When a current of electricity passes through a good conductor it does not materially raise the temperature of the conductor, but if passing through a poor conductor the temperature rises and the conductor may become red or white hot. Suppose two pencil shaped pieces of carbon in contact and a current of electricity sent through them. At the small point of contact where the greatest resistance is encountered much heat will be developed, the points will glow and the air space between reach a temperature so high that it becomes a conductor; then if the points be separated ever so slightly a brilliant light will be produced, for though the carbons themselves are hot the surface between the points offers still greater resistance to the current and the arc may have a temperature of 4800 Fahrenheit. Such an intense heat consumes the carbons and much ingenuity has been exercised in devising some efficient method of candle feed, for as the carbons waste away the arc widens until it becomes so wide that the currents are interrupted and the light goes out. This makes it necessary to adopt some mechanism by which the carbons may be made to approach each other as they are consumed and so keep the space between them constant. Usually the lower carbon is stationary and the upper one is fed down by gravity and controlled in its movements by delicate electrical devices.

In arc lights produced by continuous currents the positive carbon is hotter than the negative and is consumed about twice as fast. The points of the carbon also differ. The negative carbon wastes away to a point like a lead pencil, while the end of the positive carbon is flat or hollowed out, forming a "crater."

In arc lights produced by alternating currents these differences

exist in a less degree, but the illumination varies more. Arc lights are usually surrounded by a glass globe to diffuse the light and avoid the striking contrast of intense light and heavy shadows, but such globes cut off from 40 per cent. to 60 per cent. of the light.

The search light is another interesting example of a practical application of electricity. It consists of an arc light placed in front of mirrors made either of silvered glass or polished metal and curved so as to focus the light. The lamp and the mirrors are mounted within a cylinder hung on pivots so as to be easily turned in any direction. The front of the cylinder is covered with thin plain glass to protect the mechanism within. Search lights are made of such enormous power that they may be visible 150 miles away. The one on the observatory on Mount Lowe, California, said to be the most powerful in use in the world, is of 3,000,000 candle power and weighs 6000 pounds, yet it is so perfectly balanced in a tank of mercury that it can be easily turned with one finger.

Fire departments of great cities now use portable search lights capable of sending powerful beams through clouds of smoke and steam and lighting up dark streets, the faces of walls, and interior of buildings that otherwise shrouded in darkness would greatly increase the danger of the valiant fire fighters.

The search light is useful to ships, for it assists in detecting landmarks, reefs, rocks, and other dangers of navigation or the proximity of other vessels, and the equipment of no warship to-day is complete without one or more search lights. Large battleships frequently carry as many as half a dozen, that all sides may be lighted up or duplicate lamps provided against accident or injury in battle. By the aid of the search light torpedo boats can be seen at a distance of more than a mile and the boat finds in the search light and the rapid fire gun a combination most dangerous for her to oppose.

The incandescent light followed as a natural consequence from

the discovery of Davy and other scientists at the beginning of the century that a platinum wire could be made white hot by sending a strong enough current of electricity through it. However, the difficulty with such a lamp was that it was not economical, for at a low temperature it turns into light only a small part of the energy supplied it. Solids in general when heated emit red rays at 1000 Fahrenheit, yellow rays at 1300, blue rays at 1500, and white heat at about 2000, and if the substance be heated hotter, the light emitted is much greater proportionally, so it is economical to heat the substance as hot as possible. The trouble with the early attempt was that the most refractory metals melted at about 3450 Fahrenheit, while the electric arc easily reached 4800.

We have seen that all materials offer resistance to the passage of an electric current but some more than others; just as an auger will bore in soft wood without materially heating the wood but if the same auger be used in very hard wood heat enough may be developed to char the wood.

About 1840 Grove, the inventor of the Grove battery, devised what was perhaps the first electric glow or incandescent lamp. He described it as follows: "A coil of platinum wire is attached to two copper wires, the lower parts of which, or those most distant from the platinum, are well varnished; these are fixed erect in a glass of distilled water, and another cylindrical glass, closed at the upper end, is inverted over them, so that its open mouth rests on the bottom of the former glass; the projecting ends of the copper wires are connected with a voltaic battery (two or three pairs of the nitric acid combination), and the ignited wire now gives a steady light. Instead of making the wires pass through the water, they may be fixed to metallic caps well luted to the necks of a glass globe." Other inventors were soon in the field and after the Grove lamp came those of Starr-King, Farmer, and others, but they all encountered

the difficulty of the wasting away of the incandescent body and it was not until 1877 when the Sawyer-Man lamp was produced that any great activity was exhibited in this field. It was found that the incandescent body of an electric lamp if exposed to the atmosphere rapidly wasted away, and to overcome this difficulty Sawyer inclosed the incandescent carbon in his lamp in an atmosphere of nitrogen, which is not a supporter of combustion. Edison had also entered the field and the strife in the Patent Office between him and Sawyer-Man was carried to the courts and finally decided in his favor. There are now many kinds of incandescent lamps, the chief difference being the manner in which they prepare the carbon filament. The price has gone steadily down.

The light in an incandescent lamp is emitted from the carbon filament and the amount depends upon the temperature to which the loop can be heated without volatilizing the carbon. Filaments usually break down because the action of the current tends to disperse minute particles of carbon and deposit them on the inner side of the bulb, darkening it and shutting off some of the light. Considerable skill and much care are required in the manufacture of the filament. It is necessary to use some material that contains carbon in chemical combination with some fiber. The material chosen is given its proper form and then baked at a high temperature while preserved from contact with the air until it is carbonized. It is then heated to incandescence by an electric current in an atmosphere of hydro-carbon vapor, which coats it with carbon freed from the vapor. The last operation is called "flashing" and gives it the silver gray luster that is considered best for wearing.

Various materials are employed by the different manufacturers in preparing the filaments. In the Edison process they are made from bamboo, while in the Swan lamp a cotton thread is drawn through sulphuric acid and then carbonized and submitted to the flashing process.

When the filaments are ready to be mounted, the ends are electroplated with copper so as to form a good junction, and turned into loops and fastened to two platinum wires which penetrate the interior of the glass bulb. A vacuum is then created in the bulb by an air pump until the pressure within is equal to only about one millionth of an atmosphere and the bulb is sealed. Platinum terminals are chosen because platinum contracts and expands under heat about the same as glass and so lessens the danger of cracking the bulb. The ends of the platinum wire are carried outside and electrical connection made with them.

A current of considerable power coming through a wire of greater diameter than the thread-like filament would obviously encounter resistance in passing through so small a conductor, and frail as the filament is and appears it gives as much resistance as several miles of ordinary telegraph wire. Only continuous currents can be used for incandescent lamps and they are usually what is known as "low tension" currents, ranging from 100 to 250 volts, and would not injure a person brought in contact with them. Trolley lines usually employ about 500 volts, enough to kill animals but not necessarily enough to kill a human being. The voltage in lines feeding arc lights has increased rapidly of late years and some lines now carry high tension alternating currents ranging from 2000 to 5000 volts. Such a current could start a fire or kill a person instantly. Incandescent lamps operate under water as well as in the air and so are used to good advantage by divers. Since they do not deprive the atmosphere of its oxygen they are especially adapted to lighting the interior of mines, tunnels, dwellings, and holds of ships.

When it became apparent that the incandescent lamp was efficient it struck terror to the hearts of the holders of gas stock, and on October 11, 1878, a veritable panic occurred at the London Stock Exchange, but the field of light is broad enough for both, and the market reports show that gas is still a pretty good investment.

Electric lighting came into use with great rapidity. A quarter of a century ago it was so little used that it was an object of interest and curiosity. During the year 1899 a single company, the General Electric, is said to have received orders for more than 10,000,000 incandescent lamps, and it is estimated that the value of the electric lighting plants in the United States alone is now equal to at least $600,000,000.

Electric heating, now familiar in our electric street cars, promises to become equally well known in the household wherever cleanliness, convenience of handling, and instant availability will offset the increase in cost. The heat available is ample, for the temperature of an electric arc is variously estimated at from 6000 to 10,000 Fahrenheit, or several times that of a coal furnace, and electrical ranges, ovens, gridirons, etc., are now installed in many of the best hotels and restaurants. A flatiron having within it an electric heater connected by an insulated wire has proved serviceable. Quilts for beds are made with fine wires interwoven through which a current of electricity can be sent, maintaining a constant temperature most acceptable to an invalid. An insulated handle to which is attached a loop of platinum wire heated by an electric current is frequently used by physicians in place of the knife in cautery and by its aid tumors or other objects can be easily excised.

Electric welding was invented and perfected by Professor Elihu Thomson of Lynn, Mass., who took out his patent for the process August 10, 1886. It is one of the most interesting of the recent applications of the alternating current. A current of low voltage but large in quantity is passed through the metals where they are to be joined. Since the metals cannot fit absolutely, the surface in contact must be less than their whole diameter, and when the current is sent through the smaller portion a higher resistance is set up at the point of contact, where the temperature rises until the ends of the metals

fuse and can be forced together by simple pressure. By electric welding not only metals of the same kind but of different kinds may be joined, as brass and iron, and a small piece may be welded at an angle to a larger one; hollow pieces such as pipes or pieces irregular in outline may be welded as though they were solid, for the welding heat can be produced exactly at the point where it is needed and without detriment to any other part.

The firefly is not without interest to scientists, for that insect presents a problem for their consideration that may well be studied. It performs the marvelous feat of producing light without any accompanying heat. Professor Langley seems to have demonstrated that of the waves radiated by a gas flame only 2.4 per cent. are luminous, those from an electric arc reach but 10 per cent., and those from the sun only 38 per cent., while the radiation of the firefly consists wholly of "visible wave frequencies."

Scientists are not agreed as to the manner in which the light of the firefly is produced. One eminent authority says, "The light may continue long after the death of the cells and therefore it is not a property of the living protoplasm as such." Another states that if the luminous organs are dried and pulverized in a mortar they have no glow, but if a little water be added the glow returns and is constant. It can hardly be a form of combustion, for it takes place equally well in a vacuum, in hydrogen gas, and in carbonic acid gas, all of which are powerless to support combustion, and the intensity of the glow is not increased in an atmosphere of oxygen, which would stimulate combustion.

The electric furnace is in reality an electric arc of huge proportions and the heat developed is so intense that it fuses all known elements and heats carbon vapor so hot as to develop the true spectrum. The furnace is simple in construction, being merely a number of electrodes at each end of a firebrick structure, the connection be-

tween them being usually made by some form of carbon. A dynamo furnishes an electric current of large quantity and moderate voltage, and the carbon connecting the electrodes offers such a resistance that the arc soon reaches a higher temperature than can be produced by any other artificial means.

Various methods are employed to measure the temperature, but a common one is to put a piece of platinum into an electric circuit, increase the current until the piece is red hot or at a temperature of about 1800°. A delicate thermometer is then placed exactly three feet from the platinum and the temperature carefully noted. The electric current is then increased until the platinum becomes white hot or about 3400°, and the amount of electricity used recorded. The same thermometer is then placed at such a distance from the platinum that it will register the same temperature as before, the distance is accurately measured, and from the readings of the thermometer, the distances, and the amount of current used the temperature of the furnace is approximately determined when is is so hot that it will fuse every known substance.

Carborundum, or silicide of carbon, is a product of the electric furnace and was first discovered about 1890 by E. G. Atchison of Chicago when experimenting for the production of diamonds. He gave it the name "carborundum," for he thought he had produced a compound of carbon and corundum, but chemical analysis shows that it is silicon and carbon with a trace of iron, alumina, and lime, probably impurities, which give to the crystals a color ranging from nearly white to deep green or blue.

The crystals are almost as hard as diamonds, insoluble in acids, and do not fuse in a blowpipe flame. They are commercially valuable as abrasives, for one pound of carborundum will polish eight times as much surface as the same weight of emery and will do it in less time. Carborundum, being so hard, wears longer and cuts

faster than emery, and carborundum paper is as much superior to emery and sandpaper. Carborundum is used as a substitute for emery wheels and grindstones and is made into wheels, whetstones, and polishing cloths.

Carborundum furnaces are of fire brick and are usually about twenty-two feet long, five feet wide, and seven feet deep, with ends two feet thick. Into the brickwork of each end are built twenty-five or more bars of carbon (electrodes) four inches square and thirty inches long. These are connected by copper bars with the cables containing the electric current. The ends and bed are permanent but the side walls are temporary and are taken down each time the furnace is charged. In charging, the furnace walls are built up about half way and the interior filled with a mixture of the finest white sand, pulverized coke, and coarse salt. An equal bulk of sawdust is added and when the current is turned on the sawdust burns away and leaves the whole mass porous so the gas has a chance to escape, a very necessary measure, for with all precautions explosions are not unknown. A semicircular trough, about twenty-one inches in diameter and half as deep, is scooped out in the mixture between the electrodes and the hollow filled with coarser pieces of coke, rounded up until a core is formed reaching from one set of electrodes to the other. The core may be likened to the filament in an incandescent lamp, for it is through this core that the electric current is (later) to be passed. The core being in position the side walls are built up and the core covered with more of the mixture of sand, coke, salt, and sawdust, and the whole packed down.

When all is ready the electric current is turned on. As delivered by the Niagara Power Company it has a pressure of about 2200 volts, but for the use of the furnace is "stepped-down" by an 1100 horsepower transformer until it has a pressure of from 100 to 250 volts. About 4 per cent. of power is lost and turned into heat in the trans-

former, and its equivalent of 44 horse-power has to be taken care of by surrounding the transformer with a constant current of cool oil to carry away the heat. About half an hour after the current is turned on gas begins to appear at the sides and top of the furnace and burns with a bluish flame. It is estimated that during the process 5½ tons of gas are emitted, hence the necessity of the precautions to guard against explosions and of such an arrangement of the mass as will take up shrinkage as it grows less in quantity.

After 36 hours the current is shut off and when the furnace is cool enough the side walls are pulled down. All the impurities having been driven out of the coke by the intense heat, it is left a mass of pure carbon surrounded by a shell, 10 or 12 inches thick, of beautiful carborundum crystals, some of them one half inch on a side. Outside the layer of crystals is a layer of partly-formed carborundum and beyond this the mixture remains unchanged. One charge with fair success yields about 4000 pounds of crystals.

The carborundum is then crushed under heavy rollers and soaked in dilute sulphuric acid to get rid of the impurities, washed, screened, and graded according to the use which is to be made of it. If for grinding wheels, the material is mixed with a kind of clay and feldspar called "kaolin," placed in molds, subjected to hydraulic pressure, baked, trued up, and tested. The wheels vary in size from the minute wheel 1-16 inch thick and 1-4 inch in diameter, used by dentists, up to one 6 inches thick and 36 inches in diameter upon which has been expended 1250 horse-power-hours of energy.

The Stassano Process was one of the first attempts to make practical application of the electric furnace to the reduction of iron ore. Some of the advantages of such a process as at Sault Ste. Marie, for example, where nickel and iron ore are abundant and close at hand, and water power available, are easily apparent, for the water power can be utilized to generate electricity for the electric

furnace and save the coal used in ordinary processes. The economy of the world's fuel is an important subject, for immense quantities are now used annually and the consumption is increasing with such exceeding rapidity that the world's supply is plainly not inexhaustible. In this process the ore is first roasted and a definite percentage of carbon, calcium, or silicon, according to the composition desired, added. The mixture is then pulverized, mixed with from 5 per cent. to 10 per cent. of pitch, made into paste and pressed into bricks. The bricks are placed in a furnace which does not differ materially from the ordinary blast furnace except that there is an electric arc at the bottom which furnishes the heat, and the whole process of fusing is about like that ordinarily practiced. No fuel except the pitch employed in making the bricks is used, and about 3000 horse-power-hours of energy will produce a ton of metal.

Aluminum is also produced by the aid of the electric furnace. It is said that in 1883 there were only 83 pounds of aluminum produced by this method while in 1898 the output was raised to more than 5,000,000 pounds and the price so materially decreased that aluminum cooking utensils are now made. In view of the many absurdities afloat concerning the use of cheap aluminum for structural purposes, it is well to remember that aluminum is not so marvelously strong. Its tensile strength, square inch for square inch, is only about the same as that of cast iron, one half that of wrought iron, or one fifth that of the best steel. Aluminum is light, and, taking its specific gravity as a unit, steel is 2.95 times, brass 3.45 times, copper 3.6 times, and lead 4.8 times as heavy. A bar of aluminum shows an ultimate tensile strength of about 28,000 pounds per square inch; a bar of the best steel of the same diameter shows a tensile strength of more than 150,000 pounds per square inch, so that not only section for section but weight for weight aluminum is inferior in tensile strength to steel.

Electroplating is another practical application of electricity. Daniell is said to have noticed that the copper deposited on the copper plate in his voltaic cell reproduced even the minutest scratches on the plate, and his discovery has been called the beginning of the art of electroplating. In 1838 Jacobi described the principles to a scientific society of St. Petersburg, and in 1839 in a letter to Faraday told how he obtained copper plates which were exact copies of the medals or designs from which they had been taken. However, the early history of electroplating is enveloped in considerable dispute. It has been claimed that it originated with Volta and Wollaston, that in 1805 Brugnatelli, a pupil of Volta, gilded two large silver medals, and that in 1834 Sir Henry Bessemer electroplated lead castings with copper. A knowledge of it has even been ascribed to the Egyptians. In the temples and tombs of Thebes and Memphis, vases and urns have been found bearing a plating of copper which presents to the microscope the appearance of galvanic deposits.

If two clean pieces of metal, as platinum, be put in a solution of copper sulphate and a current of electricity sent through them copper will be deposited upon the negative or cathode pole, *i. e.*, the pole by which the current leaves the solution. By maintaining the strength of the solution and keeping up the current, a plating of any desired thickness may be deposited which when removed will give an exact reproduction of the original. In taking an impression of a medal, it is given a coating of varnish, shellac, or sealing wax, covering all except the portion to be copied, placed in the bath as a cathode pole, and the current of electricity turned on. An inverted impression is produced from which a direct copy can be made by the same process. In ordinary practice it is customary to reproduce a design by making a mold from plaster of paris, moldine, or some similar substance, brushing it over with black lead to render it a conductor of electricity, and from this mold an exact reproduction of the original design can be obtained.

Electroplating is much used in making plates for bookwork, for electrotypes give better and sharper impressions than stereotypes. A wax mold made from the engraving or page of type is brushed over with powdered graphite to render it a good conductor and copper then deposited by the ordinary method of electroplating. Fine iron filings can be dusted on the wet graphite surface of the mold and the solution of copper sulphate poured upon it and gently stirred with a soft brush. A film of copper is almost immediately formed over the entire surface, for the acid unites with the iron to form sulphate of iron, and deposits the copper.

In electroplating where the jobs are of considerable magnitude sheets of wax are run through a shaving machine which produces a sheet of uniform thickness. The surface of the sheet is rubbed with graphite dust to prevent it from sticking to the type or the engraving and the type or engraving also dusted with graphite is forced into the sheet to the desired depth. The mold is removed, the blank places built up with hot wax so that those surfaces will not touch the paper in printing, the mold again dusted with graphite and the iron filings applied, great care being taken to see that the whole surface of the mold is covered. It is then used as a cathode pole in a bath of copper sulphate and left there until a deposit of copper is formed thick enough so it can be taken off and laid face down on a plane surface. The back of the copper sheet is next brushed over with a solution of chloride of zinc, and sheets of tin foil are laid on and melted and molten type metal poured on until the plate has been given a thickness of about one eighth inch. Plates can be coated with a solution of iron almost as hard as steel, making them very durable, and in Europe this method is employed with excellent results to make plates for printing bank notes.

The same principles are employed in gold, silver, and nickel plating, and the process has been brought to such a degree of perfec-

tion that silk, laces, fruit, and flowers even have been plated. The method has greatly reduced the cost of books, maps, medals, and similar designs, for the original design can be preserved and electrotypes made from it as often as required, each of which is an exact reproduction of the original.

It has been a boon to mankind by saving many human lives, for prior to the discovery of electroplating one of the methods of gilding was to dissolve gold in mercury until a paste was formed, apply the paste with a brush to the article to be gilded, then heat it in an oven to evaporate the mercury, leaving the gold to adhere. This method was attended with fearful mortality for the fumes of the mercury killed off the workmen rapidly.

An electric cartridge, designed as a substitute for dynamite and smokeless powder in the mines, has been invented by an Italian electrician. He uses carbonates of potash and chloride of ammonia and causes the explosion by the electrolytic effect a current of electricity has upon those chemicals. One advantage claimed for the cartridge is that it is perfectly safe and inert until acted upon by the electric current, so there is no danger connected with its handling, neither are isolated magazines necessary for its storage.

The storage battery, secondary battery, or accumulator, as it is variously called, plays an important part in the economy of electric power and is largely responsible for the increasing use of electricity. In the chain formed by the steam engine, the dynamo, and the storage battery, the dynamo takes the mechanical energy from the steam engine, turns it into electricity, sends it into the storage battery, and by its electrolytic action builds up certain chemical compounds in the batteries, so unstable that they seem to unite under compulsion and fly apart whenever an opportunity is given them. The energy will remain in the form stored until the poles of the battery are connected, but when connected in a circuit the compounds are disasso-

ciated and the same electrical energy produced with which the battery was charged less the losses inseparably connected with the transformation of force.

The difficulty encountered by investigators in "polarization of cells" has been mentioned. In 1801 Gautherot, a French scientist, remarked that if a polarized cell was allowed to rest and afterward connected, a feeble current was set up in the opposite direction.

In 1812 Ritter constructed a secondary pile made of alternate discs of copper and moistened cardboard, from which when charged by a voltaic pile he drew electricity.

The first storage battery of commercial importance was constructed by Gaston Plante, in 1860, who rolled two lead plates separated by a heavy piece of cloth into the form of a cylinder and immersed them in a 10 per cent. solution of sulphuric acid. A current of electricity was sent through them for several hours and the usual chemical changes due to electrolysis occurred, an oxide of lead forming at the pole where the current entered and a spongy deposit of lead at the other pole. When the current was stopped and the poles of the battery were connected, a decided current appeared having the opposite direction. The name "storage battery" is not really a good one for it does not work like a voltaic cell but rather like a clock spring, which, being wound up by the power of the current sent from the dynamo, relieves itself of the tension at the first opportunity and discharges very nearly as much energy as was required to charge it.

In 1880 Camille A. Faure made an important improvement in storage batteries by substituting lead plates covered with the higher and lower oxides of lead instead of the plain lead sheets of the Plante system and saved the battery the work of making its own oxides. Many minor improvements have been made since then, consisting chiefly in alloying the plates with bismuth and giving them a spongy

cellular structure so as to hold the greatest amount of red lead with the least amount of weight.

The use of storage batteries has doubled every year for the past decade, and a single concern (The Electric Storage Battery Company) turns out in one year batteries to the value of $2,387,-

ELECTRIC STORAGE BATTERY, SHOWING CONSTRUCTION.

049.91. They make batteries which are remarkably light and efficient. The sheets are made from a combination of lead and zinc chlorides and are cut into ribbons one fourth inch wide. The positive plates (grids) are made with circular holes, into each of which is forced

a spiral coil of the ribbon. The grid is then exposed to chemical action which removes the zinc and produces lead oxide and metallic lead in so porous a form as to expose a great surface to the action of the battery fluid. The negative grids are made with square holes and filled with solid lead. The cells, each containing one more negative than positive element, are set in tanks made either of glass,

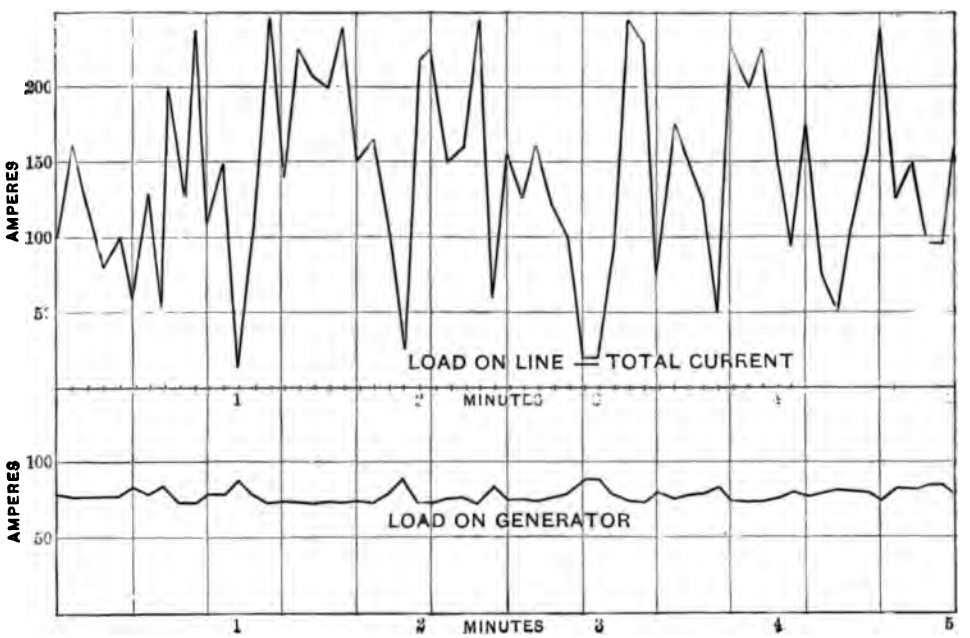


FIGURE 1.

hard rubber, or sheet lead resting on carefully insulated supports. Such batteries when charged are used by merely switching them into line where the power is needed.

Storage batteries are especially economical for small street car lines where at one time nearly all the cars may be at a standstill, making almost no demand on the power plant, and the next instant all in motion and perhaps climbing heavy grades, and testing the

highest efficiency of the generator. Before storage batteries were used to supplement the engines, the power plant had to be equal to any emergency, necessitating the use of engines almost continuously producing as much power as would be required at any instant. Now smaller engines costing less both to purchase and operate are used with storage batteries. The batteries are charged when the load on the engine is light and drawn upon for reserve when the temporary demands are greater than the engines can supply.

Reference to Figure 1 shows plainly the Economy. The irregular lines show the actual electric current required and the actual current developed in five minutes at an electric railway power house. The upper line shows the power used by the cars. The first minute started with 100 ampères, rose rapidly to more than 150, sank to nearly 50, rose in sparks to almost 250 and fell back to 10. During the first 10 seconds of the second minute the demand rose from 10 ampères to nearly 250, as is shown by the straight peak, and averaged high for the whole minute. It is evident that such extreme fluctuations would be a severe strain on the engines. Let us look at the power line. Aided by the storage batteries, the demands on the generator ran pretty steadily with little fluctuations from 75 to 80 ampères, for the batteries took care of the sudden demands for power.

A steam engine works most economically when a small amount of steam can be admitted to the cylinder at each stroke and allowed to expand. When great demands are made on the engine more steam is admitted, but the engine then works by direct pressure from the boiler, which is not an economical method, for the steadier the load the more economically can the engine be operated.

In Figure 2 the middle curve shows the variations in the current required to operate a street car line for five seconds. If a dynamo alone were to supply the energy it would need to be capable of

furnishing enough power to safely cover the highest peak, or more than 300 ampères, and when the line required less than the greatest amount there would be power going to waste. Here is where the storage battery comes into play. The upper curve in Figure 2 is almost like the middle curve, but through it runs the line marked

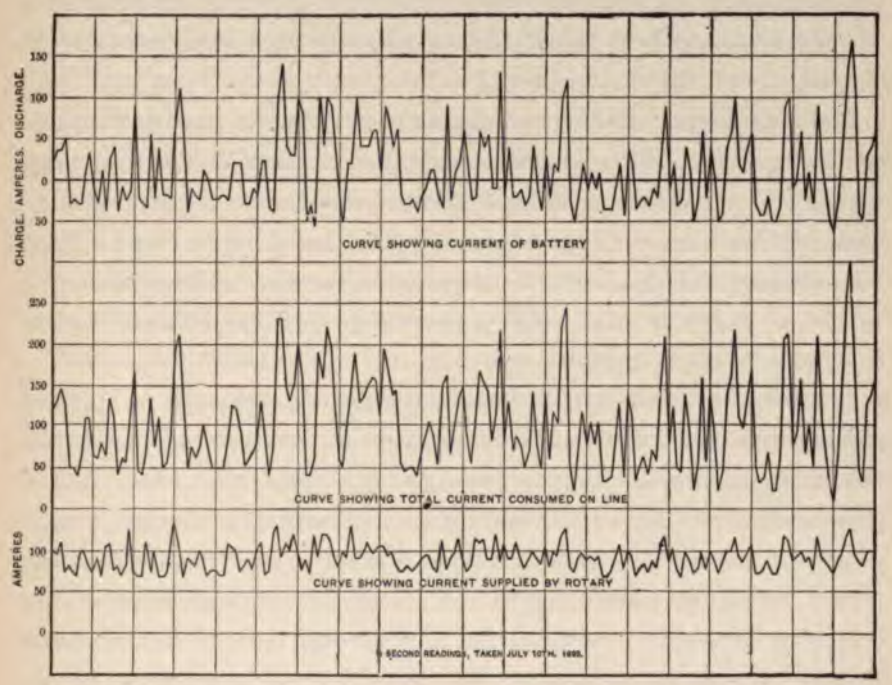


FIGURE 2.

"0," which represents the average load. When the demands for power are above this line the battery takes care of them. When the demands are for less than an average load the battery is being charged while the engines are kept running pretty steadily, as shown by the lower curve, relying on the battery to take care of sudden demands for power and to store up energy when the load is less than the average.

During the course of the day the batteries receive enough current at odd times so that in some plants the engines can be shut down at midnight and not started until seven o'clock in the morning, the batteries carrying all the night load. This gives the engines a much needed rest for inspection, repairs, etc. In many electric lighting plants the engines are run only from 4 P. M. until midnight, the batteries supplying all the lights used after that hour and through the day.

In large street railway and lighting systems it is economical to produce all the power at one central power plant, but cables large enough to carry the amount of current demanded at the extreme ends of the lines are expensive and may cost from $1 to $2 a foot. By installing storage batteries at points near the ends of the line a surplus of power is there held in reserve equal to any sudden demand that may be made upon it.

Hotels and apartment houses frequently maintain a private power plant for lighting and elevator service. When the current for the elevator is taken directly from the generator, the supply for the lights varies so much that the continual fluctuation caused is seriously objectionable. In such a plant as that of the Waldorf-Astoria Hotel, where there are 27,000 electric lights and 21 electric elevators, this is an important consideration. A storage battery in such cases supplies the sudden demands of the elevator, furnishes a steady current for the lighting system, and economizes by equalizing the load on the engines and shortening the necessary running time.

For automobiles and for propulsion and for lighting small boats such batteries are especially well suited, as they are noiseless, produce no smoke, dirt, or odor, and their weight in a boat carrying ballast to preserve its center of gravity is no objection, for the storage batteries can be substituted in part for the ballast.

In reducing aluminum by the aid of electricity large iron vats

lined with carbon are employed. Over each vat is a framework through which project numerous large carbon rods about 20 inches long and 2½ inches in diameter. The vats are filled with alumina, an oxide of aluminum, together with certain other materials, and the electric current is turned on. A large current of a low voltage is employed and the heat evolved is used only to melt the materials, for the electricity does its work in this case by its electrolytic action. The oxygen set free is thrown off as a gas and the metallic aluminum in a melted state sinks to the bottom of the tank and is dipped out by large iron ladles and poured into molds. The current, usually not exceeding seven or eight volts, is not dangerous to the person, for the human body is such a poor conductor that it is able to resist such a current, just as a thin armor might repel a light, slow moving projectile, but be pierced by one of a higher velocity.

Calcium carbide is another important product of the electric furnace. It is a compound of carbon and calcium, a white metal, not found in a natural state but existing chiefly in the form of carbonate of lime. Unslaked lime is ground into fine powder, then mixed with powdered coke or carbon in such a proportion that when the union takes place one atom of calcium will unite with two atoms of carbon and form calcium carbide. ($Ca\ C_2$.) The mixture is then put into a crucible in which is a powerful electric arc, which melts the mixture, throws off the oxygen, and unites the calcium and carbon. Calcium carbide is used to generate acetylene gas in large quantities. The gas is composed of two atoms of carbon and two atoms of hydrogen ($C_2\ H_2$) and when water is added to calcium carbide it decomposes the water and the carbon and the hydrogen unite, forming acetylene gas and leaving a residuum of slacked lime.

Electricity half a century ago was practically applied only in the telegraph. To-day the world would seem lost without it. In that familiar illustration, the street car, we find it performing three dif-

ferent kinds of work; heating, lighting, and propelling. A quarter of a century ago it was just making its appearance in the commercial world as a motive power and to-day it is a rival of steam. However, it can rarely be independent of the black slave, coal. In lands where coal is expensive and water power abundant and cheap it can compete with the steam engine, but it must be borne in mind that electricity is simply a form of energy which must be paid for. The best dynamos working under a full load are capable of turning into electricity 95 per cent. of the power applied to them. This if sent through a wire for a considerable distance will lose in the wire from 5 per cent. upward. If transformers are used to step-up or step-down the current, a loss is sustained thereby; the electric motor which takes the current and turns it into mechanical energy is about as efficient as the dynamo, so another loss of 5 per cent. occurs. It is probable that some means of conducting electricity for long distances without such great waste will eventually be devised, every waterfall harnessed, its power turned into electricity and conveyed where it can turn motors not only to run the usual machinery but to cool rooms, bake bread, run sewing machines, and perform the thousand and one other things connected with the labor of the household.

The steam engine can turn into electricity only about 15 per cent. of the power latent within the coal, and a fortune awaits the man who can utilize the large margin wasted and turn coal directly into electricity. Chemists have demonstrated that it is possible but have been unable to perform it profitably. However, electricity has made such rapid strides that at the close of the century it was estimated that in the United States the capitalization in electrical appliances was about equal to the national debt.

IRON AND STEEL WORKING.

Iron Ore, how mined, transported, and smelted — Steel and Its Relation to Modern Progress — Crucible Process — Bessemer Process — Open-Hearth Process — Advantages of Each Process — How Steel Castings are Made — Alloys — Testing Machines — First Iron Works in America — First Iron Works in Canada — Ore Deposits of Canada and Newfoundland — Iron and Steel Production of the World — Bridges — Reasons for High Buildings and How they are Built.

WHEN primitive man subjugated fire he achieved a great victory over natural forces, but when he applied its magic touch to the dull sodden mass of iron ore that lay hidden in the bog or on the mountain side, he laid the corner stone of the foundation upon which the structure of our civilization is reared. No other discovery has been so beneficial to man as the mastery of iron and its derivative, steel. If the statement seems strong, picture society with those metals removed. With them would vanish the railroad, the steamship, the steam engine, the telegraph, the telephone, mills, factories, firearms, agricultural machinery, all tools with cutting edges, the instruments of the astronomer, the chemist, the surgeon, and the whole fabric of civilization reared by the rise of intelligence above brute force.

The early ages of antiquity have been commonly divided into the stone, bronze, and iron, but some metallurgists think that iron should take precedence over bronze and encourage the supposition that bronze was a substitute for rather than a forerunner of iron.

An eminent English metallurgist says, "It has always appeared to me reasonable to infer from metallurgic considerations that the age of iron would have preceded the age of bronze. The primitive method, not yet wholly extinct, of extracting iron from its ores, is a much simpler process than that of producing bronze and indicates a much less advanced state of the metallurgic arts. In the case of iron all that is necessary is to heat the ore strongly in contact with charcoal; whereas, in the case of bronze, which is an alloy of copper and tin, both copper and tin have to be obtained by smelting their respective ores separately to be subsequently melted together in due proportion and the resulting alloy to be cast in molds requiring considerable skill in their preparation." *

The Scriptures ascribe the working of iron to Tubal-cain, and it is certain that it was known to the Assyrians and Egyptians at a very early period in the history of the world. The Israelites labored in iron furnaces under their Egyptian taskmasters, and since iron ore is not found within the borders of Egypt it speaks volumes for the civilization and commerce of a country that could at that age gather the ores from a distance.

Rich iron ore is now found in Algeria near the site of ancient Carthage, and it is reasonable to suppose that the Carthaginians a thousand years before Christ were not behind their Egyptian neighbors in the knowledge of the use and manufacture of iron Chinese literature says that it was known in that country two thousand years before Christ, and in that other cradle of early civilization, the Valley of the Euphrates, iron ore of considerable richness is yet found. It seems but characteristic of England that at the advent of the Christian era, English ships were carrying English iron to continental markets.

It is not within the scope of this article to take up the history of

* Dr. John Percy.

iron, but rather to trace it as it comes from the mine until it appears as a finished product applied to the service of man. The Lake Superior district has been selected for description because the methods of mining, handling and transportation there employed represent the very acme of scientific organization.

Lake Superior Iron Ore. Perhaps the richest iron deposits in the world are found surrounding Lake Superior. The strata there make a great dip and the lake occupies the depression, the bottom of it being 406 feet below sea level. The ore appears on both sides of the lake, but the beds on the northern side are deeper than on the southern side and are not yet much worked. Those on the southern side may be divided into five districts. The first, at Marquette, Michigan, was opened in 1845 and the ore was reduced in local forges, the adjacent forests furnishing cheap charcoal used in the process; but with the increasing demands for iron and the change from the charcoal to the coke process it became cheaper to ship it to blast furnaces situated near coal mines, and in 1856 the first important movement toward the furnaces of Pennsylvania began, 5000 tons of ore being shipped that year.

The second district, that of Menominee, Michigan, was discovered about 1848, but no considerable shipments were made from it until 1880. The Gogebic district lies both in Michigan and Wisconsin and was discovered about the time of the preceding and opened in 1884. The Vermilion range of Minnesota was discovered in 1866 and by 1884 was in full operation.

The richest district and most easily accessible ore is also in Minnesota and is known as the Missabi range. A little ore was obtained from this range in 1850, but the mines were not systematically developed until 1892. Now the output from that district exceeds that of the others combined, and in 1899 it was estimated that there was in sight, in the Missabi district alone, no less than

400,000,000 tons of ore that needed only to be shoveled into the cars. "Among the movements of raw materials in the commercial organization of iron and steel manufacture the most noteworthy in the amount of materials handled, in the methods of handling them, and in the scope of the mark reached by them is the movement of iron ores from the territory along the western and southern shores of Lake Superior to the southern shore of Lake Erie and thence to the furnaces of Western Pennsylvania and Ohio where the coal deposits lie. This movement is in fact the most important feature in the American ore trade as well as one of the conspicuous features of the internal commerce of the whole country. From mine to furnace the ore is carried from 800 to 1000 miles in barges and vessels, carrying from 7000 to 9000 tons of ore each, at the rate of more than 3,000,000 tons per month." This ore is moved at a fuel cost of about ½ ounce of coal per ton-mile and at a speed of 10 miles an hour, while, according to the War Department reports, the average cost for five years of moving a ton of freight a mile on the Great Lakes has been less than one tenth of a cent, and for 1898 the cost was .79 of a mill. There is probably no other similar freight movement in the world, for the iron ore alone that passes through the canals at Sault Ste. Marie is greater than the net tonnage of the Suez Canal, and both in point of magnitude and in method of handling it well represents the highest excellence in mine management and water transportation. In 1899 the iron ore output of the world was 84,064,000 tons, of which the Lake Superior district produces 18,251,804 tons or nearly 22 per cent. of the total production of the world.

"In this age of engineering and industrial marvels nothing is more striking than the methods employed in the transportation of iron ore from the mines in the district surrounding Lake Superior to the furnaces in the Mahoning Valley and the vicinity of Pittsburg. Almost every link in the whole system is unique. Nowhere

else in the world is freight moved so cheaply as on the Great Lakes, and nowhere else are cargoes transferred from cars to ships and from ships to cars with such rapidity. The whole plan of handling iron ore from the time it is taken from the ground until its conversion into pig iron has, by reason of the economy of time and money involved, excited the admiration of the great numbers of foreign engineers who have within the past few years visited the lake district, and has been one of the principal factors in introducing a proper appreciation of the possibilities of American competition in the future." *

There are four systems of mining in general use in the Lake Superior districts; namely, overhead stoping, caving, milling, and steam shoveling. In overhead stoping a shaft (tunnel) is sunk into the rock underlying the vein of ore but always with a firm wall of rock between it and the deposit of ore. The ore is found in veins between strata of rock and the strata and veins do not run horizontally but dip, and as the shaft runs parallel with the vein it is always at a slant. One of these shafts, 21 feet wide and 7 feet high, has already reached a depth of more than 1000 feet, but the shaft is not pushed any faster than the removal of the ore requires.

When a shaft has reached the proper depth, usually 62 feet below the top of the ore to be removed, a horizontal "heading" or gallery is driven through the rock wall between the shaft and the vein of ore and through the ore to the rock on the opposite side. In this main heading a number of cross headings 12 feet long are driven at right angles to the main heading. This maps out a block of ore 62 feet high, 24 feet wide, and as long as the vein is thick. The miners, beginning at the bottom of the 62-foot block, remove the ore with picks and throw it behind them, from whence it is carried away or left to form a basis for other workmen to stand on and attack the

* Waldon Faucett in the *Engineering and Mining Journal*.

wall of ore at a greater height. As fast as the ore is removed heavy timbers are placed in position to sustain the overlying mass and prevent caving in. A good illustration of the whole operation would be to suppose gangs of men working on the under side of a gigantic stairway of ore, a crew of men digging away at the back of each step. When the block has been worked out, one of the short headings is pushed out on one side an additional twenty-four feet, the ore overlying it left as a pillar to help hold up the roof, and another block or room like the first is worked out beyond it

When the two rooms separated by the pillar of ore have been worked out the timber is collapsed by dynamite and the pillar of ore worked out by the caving method. The shaft is then sunk sixty-two feet further and the operations repeated until such a depth is reached that the difficulty of pumping out the water which floods the mine renders further work unprofitable.

The caving system is a safer method than overhead stoping because the timber supports are never more than seven feet high as against the sixty-two feet in overhead stoping. In the caving system a vertical shaft is sunk into the rock to the depth of 100 feet just outside the body of ore. At the bottom of the shaft a heading is driven through the rock and ore from which a system of horizontal headings branch out until enough surface has been covered to furnish all the ore that can be profitably hoisted through one shaft. After the headings are finished the miners begin at regular intervals along them and dig holes resembling wells, only they are commenced at the bottom and progress vertically until they reach the top of the body of ore. These wells are called "rises" and are about 3½ feet wide, 7 feet long, and as deep as the mass of ore blocked out, usually 100 feet. Each rise contains a ladder-way and a "chute." On reaching the top of the body of ore the rises are connected by well timbered tunnels 7 feet high, and when these are completed a slice

7 feet thick is taken off the top of the ore bed, thrown down the chutes, hauled through the headings to the shaft, and hoisted to the surface. As fast as the ore is removed the overhanging mass of rock is supported by vertical timbers seven feet in height. When the first layer has been removed timbers are laid over the floor to make a solid roof for the next slice. Dynamite is exploded under the supporting timbers and the overlying mass of rock and earth sinks seven feet and falls upon the timber floor prepared to receive it and act as a roof for the next operation. So slight a fall is not likely to cause as much damage as the 62-foot drop of the overhead stoping method. The miners begin work under the timber roof and remove another layer of ore and repeat the method.

Milling is a modification of the caving system, but here the entire overlying material is removed or stripped off and the miners at work on top of the ore are in a deep pit instead of a cave and have the advantage of open air, good ventilation, and sunlight. There is no extensive timbering and the danger of caving in except along the side is avoided. The great expense involved in removing the overlying material if the ore is not near the surface is the great drawback to this method. The caving method is usually the cheapest and the one most widely used where deep-seated ores have to be removed.

The steam shoveling method is the most rapid of all, but cannot be used unless the ore comes within 40 or 50 feet of the surface. The average depth of the Missabi deposit is not more than 20 feet from the surface and excellent drainage can be secured from deep cuts. One layer or cut taken out by the steam shovel lays the ore bed bare, and all that is then necessary is to shovel it directly into the cars, for the ore is not very dense and blasting is not often necessary. After the covering is removed railroad tracks are built right into the heart of the deposits and extended as the operations demand. The ore is usually removed in steps from 20 to 30 feet

high, and on each step is laid a track with three branches; one for the steam shovel, one for the cars being loaded, and one for empty cars and switching, so that no time is lost, for it is desirable to keep the steam shovels steadily at work.

Description of the Steam Shovel. The steam shovel deserves a few words of description for it performs an enormous amount of work, lifting five tons of ore at a stroke, and filling a 25-ton car with five shovelfuls. One shovel has been known to take 5825 tons of ore from the bed and load it on a car in one day of nine hours. The car on which the machine is mounted is strong, solid, heavy, and about the size of an ordinary passenger car and contains a boiler and the engines necessary to operate the shovel. From the end of the car projects an arm at an angle of 45 degrees pivoted so that it can be turned through three fourths of a circle. At the end of the arm is a movable beam to the lower end of which is affixed the bucket, a massive steel affair resembling a gigantic coal hod. From the lower side of the open end of the bucket project a number of great steel fingers.

In operating, the shovel is pressed against the bank near the bottom and as the shovel is drawn against the bank with an upward sweep the fingers loosen enough ore to fill the bucket. The whole is then turned on the pivot until the bucket hangs over the car at the other side, a chain is pulled and the contents of the bucket fall out through a trapdoor at the bottom, into the car. This shovel performs the work formerly done by men with wheelbarrows and requires ten men to operate it and 500 pounds of coal each hour to feed the engines, but it has reduced the cost of mining at the Missabi range from $1.05 a ton to 20 cents a ton. The mines are operated continuously but the lakes and canals are open for navigation only seven months in the year, so the winter output is stacked up in great piles awaiting the opening of the shipping season.

Special cars with trapdoor bottoms are used for hauling the ore. These cars are hauled to the ore docks on a trestle over the ore pockets. When in the proper position the trapdoors are opened and in a twinkling the whole carload is deposited in the ore pocket.

Ore docks, especially constructed for the needs of the traffic, are built at the water's edge so that vessels can come immediately alongside them. An ore dock is in itself a novel sight, ranging in length from a few hundred feet to more than 2000 feet and rising from 50 feet to 73 feet above the water. Two docks at Duluth are each 2336 feet long and have a united storage capacity of more than 126,000 tons of ore. The structure resembles a huge trestle on top of which is laid a track for the ore trains. The bottom of the trestle is many feet above the deck of the ship and is divided by partitions into compartments called "pockets," from each of which an inclined "spout" leads out to where it can discharge by the force of gravity the contents of the pocket directly into the hold of the waiting vessel.

An ore fleet of several hundred vessels, mostly of steel construction, many of them between 400 and 500 feet in length, and carrying from 5000 to 8000 tons, takes the ore from the Superior docks and distributes it among the southern ports of Lake Erie. Until the advent of the Rockefeller interests in the iron trade all classes of vessels were pressed into carrying ore, but now it is chiefly carried by those especially designed to carry the greatest weight at the least expense during the short season. Since the mines and the furnaces must be kept continuously in operation, the transportation facilities must be able to carry as much in seven months as the furnaces will use in a year, and as all time not spent in actual travel is so much time lost, the loading and discharging of the vessels is carried on with the utmost dispatch, some of the great companies even preferring to send their boats back empty, rather than take time to load them with coal or other freight for the return trip.

Two types of vessels have been evolved. One has a flat deck with the boilers and engines as far astern as possible and the bridge, masts, and deck houses piled up in the space forward. All the intervening space is left for the ore, and to afford easy access to the hold, hatchways are placed with their centers 24 feet apart, nearly the whole length of the deck. These vessels carry about 6000 tons of ore when drawing 16 feet 8 inches of water, no greater draft being possible on account of the lack of water in the locks of the canal at Sault Ste. Marie. Whalebacks represent the other class. These are of the same general build and dimensions except that the top of the vessel is rounded, which saves material, allows the sea to break over it easily and is said to give a stiffer vessel and more cargo room for the same weight of hull. The whalebacks are usually operated in trios, one being provided with the engines and the other two taken in tow. In Rockefeller's "Bessemer Fleet," a single engine is thus able to take two barges in tow, and steam the whole course at an average speed of 11 miles an hour, moving cargoes representing 20,000 tons of ore.

When an ore boat arrives empty at the ore dock it is placed so that the hatchways are opposite the alternate ore pockets. Spouts leading from the pockets are lowered over the hatchways, a gate is opened, and the ore is precipitated into the hold. When one set of pockets is emptied the boat is moved ahead twelve feet and the ore in another set discharged. All this time trains of loaded cars from the mines may be running on to the trestle and discharging their load of ore into the pockets and so directly into the boat. A vessel can be loaded at the rate of from 1000 to 1600 tons per hour and it is seldom that a boat spends more than two or three hours in getting its load. The unloading at the lake ports, though not quite so rapid as the loading, is performed without waste of time.

So many novel methods and new machines have been introduced

in handling ore that these lake ports receive frequent visits from engineers from other parts of the world interested in such subjects. One of them says: —

"The ore is unloaded on all of these docks by machines of one of three general types; namely, the whirler or revolving derrick, an automatic unloader, or the bridge-tramway type of hoisting and conveying machinery. The latter is in by far the most general use. The apparatus is found in many different forms but in all the general characteristics are the same. In each case there is an elevated bridge or tramway which spans the dumping ground or railway tracks on which are the cars to be loaded. On this travels a trolley to which is attached a bucket capable of holding about one and one half tons of iron ore. In some instances the machine is operated by one engine and in others by two, it being possible in the case of the latter to hoist and convey the buckets simultaneously. The bridge tramways are frequently built in plants of three or four bridges, each bridge being supported in front by an independent pier which permits it to be moved so as to suit the hatches of a vessel. The huge buckets are loaded by gangs of men in the holds of the vessel and when they have made the trip along the tramway the contents are discharged automatically. In some instances round trips have been made from the hold of a vessel to the extreme end of the bridge and back, a distance of 600 feet, in less than a minute."

Machines for Handling Ore. "The machines on which the best records have been made are what are known as 'direct unloaders.' These machines, instead of the long bridges, have bridges of about 40 feet in length and aprons which extend over the vessel side of the dock to an equal length. There is room for three railroad tracks under the cantilevers and two under the machine, and yet the buckets have to travel but a comparatively short distance.

"The whirlers or revolving derricks are of the ordinary type, and

are of course not nearly as speedy, while the automatic unloader previously mentioned is as yet too much of an experiment to permit many predictions regarding its usefulness. Suffice it to say that it is designed to do away with the shoveling of the ore into buckets by men in the vessel holds. One of these machines has been erected on the Carnegie docks at Conneaut, and it is hoped to bring it to a state of perfection in a short time. It is now reported that two more of these machines have been ordered.

"**The automatic unloader** consists primarily of a clam shell type of shovel attached to a mast which revolves in a complete circle, and in which an operator is stationed. The mast is in turn attached to a walking beam by which it may be lowered through the hatch of a vessel. When the shovel has been closed it is lifted from the vessel and run back over the car into which the ore is to be loaded. It is claimed that when perfected the machine will handle fully 300 tons of ore per hour.

"**With the bridge tramway apparatus** at present in use some very surprising records have been made. At almost any of the Lake Erie ports, vessels carrying cargoes of from 3000 to 5000 tons are unloaded in a single day, and next season it will be possible at the better equipped docks to take 7000 or 8000 tons of ore from a boat in nine or ten working hours. Some of the best records which have thus far been made are as follows: 4284 tons from the steamer *Yale* in eight and one half hours; 4867 tons from the barge *Aurania* in nine and one half hours; 5025 tons from the steamer *Watt* in nine hours; 5226 tons from the steamer *Stephenson* in nine and one quarter hours, and 5500 tons from the steamer *Linn* in nine hours."

The Cantilever Crane. For years it has been apparent that the ancient wheelbarrow method of unloading iron ore was wasteful, but when in 1883 Alexander Brown proposed to the ore men to do this work with an enormous cantilever crane they regarded the price

he asked for his machine as prohibitive, but with something of the same faith in his machine that Watt and Boulton had in their engines when they offered to accept in payment one third the saving in coals, the manufacturers of the crane agreed to wait for their pay until the saving in cost of unloading, over the wheelbarrow method, had equaled the price of the machine. Their faith was well founded, for the machines were paid for before the first season had expired and there are now in operation along the lakes more than 200.

Enormous cranes with trusses 353 feet in length were used on the Chicago drainage canal, where one machine made a record of handling 900 cubic yards of material in a day, taking it from a channel 36 feet deep and dumping it on top of a bank 80 feet high.

THE CANTILEVER CRANE.

The cantilever crane is a huge truss or beam balanced at the middle with a track extending the whole length, on which a traveler or small carriage runs. The traveler can be stopped at any point and from it a pulley with a wire cable running through it can be raised

or lowered. To the pulley can be attached anything to be removed, and in handling ore it carries a large bucket that holds over a ton and a half.

The truss rests on a heavy car that contains the machinery for operating the whole apparatus. Ordinarily a track parallel with the work to be done is laid, on which the car supporting the truss runs back and forth about twice as fast as a man can walk. In unloading ore ships, the ships tie up at a wharf parallel to a track on which the crane runs. The crane is brought opposite the hatchway from which the ore is taken. The traveler is run out until it is over the hatchway, a bucket attached to the pulley is lowered, filled with one mighty scoop, and raised toward the traveler, which may be already starting back on its journey to the other end of the truss 100 or 200 feet away, and perhaps the whole machine will be moving over the track laid for it to some other point where the ore is to be deposited. Electricity is used as a motive power and the whole operation is controlled by one man.

The cantilever crane is economical in power and time. With revolving cranes the whole machine has to be started, stopped, and started the other way with every load of the bucket. In the cantilever, the truss remains stationary and only the bucket and traveler do the moving. Such cranes are used at the Duquesne furnaces of the Carnegie Steel Company to carry ore from the piles where it is stored to the furnaces. These cranes have a reach of 236 feet and at each movement carry seven tons of ore.

The load that the crane can safely support depends upon the position of the traveler. At the extreme end of the beam about 8000 or 9000 pounds may be carried with safety, the amount increasing rapidly as the traveler goes toward the center. In shipbuilding the traveling crane is especially efficient. A high trestle is made on which the carriage runs and cantilevers long enough to reach from

any part of the ship are used. Steel plates, beams, engines, and machinery are by its aid very quickly deposited just where they are desired and the cantilever has come to be a recognized necessity in every well appointed up-to-date shipyard.

ORE HOISTING AND CONVEYING MACHINERY AT THE PENNSYLVANIA COMPANY'S DOCKS AT ASHTABULA HARBOR, OHIO.

Built by the King Bridge Co. The aprons which are lowered over the hatchways are seen on the right and the stock piles are to be seen on the left. Between them are the tracks where the ore is loaded directly on the cars.

In 1899 the price of iron ore at the mine in the Lake Superior district ranged from 78 cents to $1.41 a ton, and No. 1 foundry pig iron sold in the market at from $12 to $25 a ton, averaging for the year $19.36. Since the cost of the ore at the mine is such a small part of the cost of the finished product, it is easy to see how every improvement in methods of mining, loading, shipping, unloading, or carrying by rail have aided materially in reducing the price and making it possible for American iron to enter foreign markets. Among these improvements none is more marked than the substitution of the cantilever crane for the wheelbarrow.

In order to reduce the cost of the iron ore delivered at their works in Pittsburg, the Carnegie Company purchased a road running from their own docks at Conneaut, Lake Erie, to their furnaces at Duquesne, a distance of 153 miles, and carried the ore on a road controlled by their own company, handled in solid trains, and at such a saving that it gave the lowest ton-mile cost of any road on the American continent reporting to the interstate commerce commission. They also employed the latest and best machinery not only to unload their boats in Conneaut harbor but also at the other end of the line to transfer the ore from the cars to the stock piles and from the stock piles to the furnaces.

The mechanical ore unloader on their docks at Conneaut takes up 10 tons of iron ore at a bite and will transfer 300 tons of ore per hour from boats to cars. Working in the hold of a ship it will remove from 90 per cent. to 95 per cent. of the ore there and requires only two men to operate it and three men to remove the ore from the inaccessible parts of the ship and bring it where the machine can get at it. Much of the ore is smelted at Cleveland, Lorain, and other Lake Erie ports, but the greater part of it is carried to Youngstown, Pittsburg, Duquesne, and other points where fuel is cheap and convenient, for the fuel and limestone required weigh more than the ore.

Electro-Magnetic Concentration of Iron Ore. Iron is not mined in a pure state but has associated with it impurities or materials known as "gangue" which in the furnace form slag or dross, and if these are allowed to go into the stock pile they must be transported, handled, melted, fluxed, and disposed of at the furnace at great expense, while if the ore can be carried first to a separator these may be gotten rid of and only the remainder known as "concentrates" handled. If an ore containing 50 per cent. of iron be passed through a separator that can increase the amount of iron to

65 per cent., it will enable an average furnace to so increase its output as to materially lessen the cost per ton, and as the concentrate runs more uniformly than the crude ore, it is much better suited for steel making. Sulphur and phosphorus are found in some ores and if present, except in small quantities, render the iron unfit for steel making.

Magnetic Separators. Several methods have been employed to remove the impurities from the iron ore, the better to fit it for the furnace. Among other means, magnetism has been employed and patents for magnetic separators were issued a half century ago, but as they used an electric current from a voltaic battery to produce their electro-magnets, they were not a financial success, and for this reason were impracticable until after the invention of the dynamo. Since that time many patents for magnetic separators have been taken out, but one issued to Edison in 1880 is the basis of the commercially successful ones. Since Edison's patent many improvements have been made, the more recent being those of Wetherill, 1896, and Payne, 1900, but they all work on the same principle. The ore as it comes from the mine is crushed between heavy rollers until the pieces are small enough to be readily acted upon by strong electro-magnets. It is then allowed to fall in a thin sheet, passing in its course within the field of the magnets. These exert enough influence on that part of the ore that is rich in iron, so that, instead of falling in a straight line, it is drawn a little to one side, and separated from the worthless portion. This was the method employed by Edison, who set up thin knife-edged partitions where the stream of falling sand separated, caught in troughs that portion rich in iron, and led it away. The ore was made to fall from a considerable height and pass in its course before several magnets. Although what was saved was rich, yet some was lost that was worth saving.

Another type of machine carried the ore on a broad belt under

the magnet, the magnetite being lifted out of the mixture and the non-magnetic mass carried off and dumped by the belt. Between the first belt and the magnet was run a second belt at right angles, and the ore, striving to reach the magnet, was caught by the under surface of the second belt and carried out of the field.

Each of these methods required powerful magnets with a broad surface exposed at the pole, and of course as the magnetic field was spread out it became weakened and less effective.

Wetherill's improvement consisted in making more powerful magnets and bringing the poles down to a tapering form, so as to decrease the area. He arranged his magnet so that the poles were in the same horizontal plane and very close together, and passed over each pole a belt with a narrow gap intervening between the poles. The ore was fed from above and falling between the poles that part not subject to magnetic attraction dropped through, but the magnetite, trying to reach the poles of the magnet, struck the belts, clung to them, and was carried out of the magnetic field. This machine was a marked improvement and was able to separate 95 per cent. of iron from the magnetite at one operation. The machine was slightly modified and the ore fed from the under side in handling very finely pulverized ore.

Since the iron is not distributed uniformly throughout the ore a saving is sometimes effected by crushing it very finely. A piece of ore ¼ inch in diameter containing magnetite and "gangue" in the proportion of three to five will go into the tailings, but if it be crushed finer some of the resulting small pieces may contain magnetite in the proportion of five to three and these will be saved.

Separating Sand from Iron. At some places on Long Island sand is found containing 26 per cent. of the finest iron known, but it has with it titanite iron, a substance that renders it unfit for smelting. When Edison discovered that titanite was less magnetic than

pure iron he made a separator consisting of a V-shaped box with a slit in the bottom through which the sand fell in a sheet before a strong magnet that deflected the pure iron in falling enough so it could be separated from the rest. The machine cost about $700 and with a boy to run it could treat 100 tons of sand a day and extract from it about 20 tons of fine iron ore at a cost of about $1 a ton, while the ore was worth $6 a ton.

Iron Smelting.

The iron which we see in use in everyday life is not found in that form in the mines, and even in the arts pure iron is almost unknown, for the whole range of iron and steel is a series of alloys, of which carbon is the one that affects its physical wants most, although nickel, chrome, and manganese each have their special action upon it. The iron of trade is obtained from ores which are oxides of that metal, mixed with lime, clay, rock, or other impurities, and to be worked profitably must contain at least 20 per cent. of iron.

PRINCIPAL IRON ORES.

	NAME	COMPOSITION	PERCENTAGE OF IRON
1.	Magnetic iron ore	Iron and oxygen	72.41
2.	Red hematite	Iron and oxygen	70
3.	Brown hematite	Iron, oxygen, and water	61.6 (water 12)
4.	Spathic iron ore	Iron, oxygen, and carbonic acid	48.2
5.	Black-band	Iron, oxygen, carbonic acid, clay, and coal	20 to 35 (coal 10 to 25)

The principal iron ores of commerce are reduced by heating them with some form of carbon, as charcoal, coal, or coke. The carbon unites with the oxygen, passes off as gas, and the metallic iron melts, tends to free itself from other impurities and falls to the bottom of the furnace. In common practice layers of iron ore, coke, and limestone are put into a furnace, fire applied, and the whole blown with powerful blasts of air to produce great heat, hence the

name "blast furnace." The limestone and other impurities are put in as a flux to guard the iron and help carry off the impurities.

The origin of the reduction of iron is lost in the mystery surrounding the ages before history began. The first method may have been merely to build up a pile of layers of ore and wood and set fire to the mass. This would give a small quantity of fairly good iron at a great waste of time, ore, and fuel, but in an age when the latter were not important considerations. Probably the next step was to build the pile on an elevation where it would be exposed to currents of air. Next, to concentrate the heat, a hole may have been dug in the ground and the pile built in that, and the next step would be a tunnel leading from the pit and pointing in the direction of the prevailing wind. When the bellows was invented its application to the furnace was an easy step.

The cut shows an illustration of a very ancient method employed in India. The furnace is built of clay and at the bottom are two hollow bamboo tubes, the rude progenitor of the modern tuyère. A goatskin bellows with a hole in its cover connects with each tube. To the cover is attached a string leading up to a spring pole. The workman operates it by drawing up the bellows, covering the hole with his heel, stepping upon it, depressing it by his weight and forcing the air it contains through the bamboo into the furnace. The furnace is fed from the top with ore and fuel as required, and the impurities in the form of slag run off through an opening at the side near the bottom, the metal falling into a hollow at the bottom of the furnace. Such was the method employed in India at Chalybia, from which we derive our modern "chalybeate."

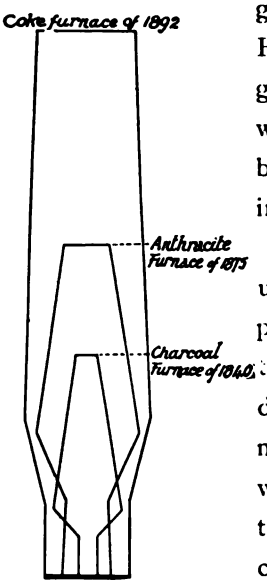
PRIMITIVE IRON FURNACE, INDIA.

The Persians are said to have invented the bellows in the form now known, to have introduced the use of charcoal, and made considerable improvements in iron smelting. One of their furnaces, at its best but "a basin shaped hole, 6 to 12 inches in depth, and 12 to 24 inches in diameter, was first made in the earth; this cavity was then lined with moistened charcoal dust, which was well rammed to make it as dense as possible; the hearth thus formed was then filled with charcoal, on which was placed a layer of crushed ore, and over this alternate layers of fuel and ore until the heap was of the desired height; the outside of the mass of charcoal and ore was then incased in a covering of rough stones laid in a mortar of clay and sand, or, in some cases, it was merely plastered over with a thick layer of such mortar; care was always taken to have a hole near the bottom, just above the edge of the hearth, for the insertion of a tube of baked clay to serve as a tuyère, and a second hole at the top for the escape of smoke and gases. Fire was then introduced at the tuyère and the bellows connected, a gentle blast being used until all the moisture of the ore and the covering of the heap was driven off. As soon as this was accomplished, the blast was increased and the heat thereby augmented. At the end of several hours, a mass of metallic iron weighing twenty to thirty pounds was found at the bottom of the hearth, from which it was removed by tongs and forged by sledge hammers into the desired shape, several reheatings being required. The iron obtained was not usually over 20 per cent. of that in the ore, and only the richest ores were used."

For many centuries the iron furnaces of Europe were of the most primitive kind, and although a good quality of iron and steel was produced in them the quantity was limited. The only changes of importance up to the middle of the eighteenth century were the enlargement of the furnaces and the substitution of water power to drive the blast. Even at that time the best furnaces were of very

simple character and the modern blast furnace is distinctly a product of the nineteenth century and more especially of the latter half of that century.

The Use of Coke Begun. Until 1735 charcoal was almost universally used as a reducing fuel, but at that date coke was successfully used in the manufacture of pig iron by Abraham Darby of England, and by 1750 its use had become general in that country. Its introduction into America was much later, and although the first rolling mill in Western Pennsylvania, built at Plumsock in Fayette County, in the heart of the present Connellsville coke region, attempted in 1817 to make use of a kind of coke they met with little success. In 1835 gray forge iron was successfully made in Pennsylvania by the use of coke and it soon became generally used and greatly increased the production of iron. William Firmstone, who was born in England and emigrated to America in 1835, is generally credited with having introduced into America the hot air blast and the use of coke in the manufacture of iron.



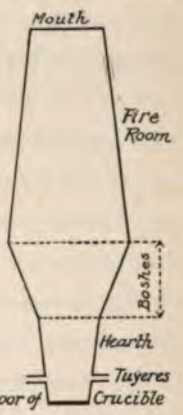
GROWTH IN SIZE OF BLAST FURNACES.

Some reasons why charcoal was so generally used in the United States were: the lack of transportation facilities for bringing iron ore and coke together, the fact that not all the bituminous coal discovered was suitable for making coke and its manufacture was not well understood, the country was poor and had an abundance of timber of which the settlers were glad to get rid, and, finally, charcoal iron was popularly supposed to be the best.

The accompanying cut shows the remarkable increase in size as well as the change in outline in the blast furnace within a period of a half century. Not so very

long ago it was thought that massive stone walls were necessary to confine the heat in the furnace, but the walls have become thinner and thinner until now they are a mere shell of iron lined with fire brick.

The fire brick so extensively used in iron smelting need to be frequently renewed, not because they are burned out by the fire, for the brick are infusible at ordinary furnace temperatures, but because the iron unites with the silica in the brick, forms a melted slag, and the bricks become spongy and are eaten away. It is essential that fire brick contain as little lime, soda, potash, and other substances likely to fuse with the iron as possible, so a peculiar kind of clay, deposited as fine sediment where rank vegetable growth has absorbed a large proportion of the undesirable elements, is employed. In the brick made from the plastic clay of New Jersey the material is first burned, then ground and mixed with enough plastic clay to form bricks, when it is molded and again burned. Such brick are able to withstand great heat but possess little power to resist mechanical stress, so are used only to protect from the action of the fire the other materials having other necessary qualities.



PARTS OF BLAST FURNACE.

The interior of a blast furnace has something the same outline as a lamp chimney. The straight part at the bottom of the chimney is called the "hearth," the sloping sides up to where it reaches its greatest diameter are called "boshes," the lower part of the hearth is called the "crucible," and at the upper part of the hearth are from one to many openings called "tuyères," through which the blast of hot air is introduced. The shaft proper above the boshes is frequently built upon iron pillars and stands permanently, while the boshes and hearth are taken down and relined or changes made in them without affecting the shaft. The furnace is charged through the top and is

closed by a cone-shaped iron cover held in place against an annular projection by the pressure from within and a counterweight from without.

The Process of Smelting. The charge, made up of crushed ore, coke, limestone, and any other materials that the quality of the ore to be smelted requires, all arranged in the right proportion for the grade of iron to be made and the kind of ore that is used, is placed on top of the cone and when needed the cone is lowered a few inches, the material slides down its sloping sides, the cone is drawn back and the opening closed, thus saving for later use the heated products of combustion that were formerly allowed to escape. Before the charge is introduced the furnace is heated by a charge of fuel, and once warmed up it may continue in operation for a year or more without being allowed to cool down. The charge is admitted to the top slowly until the furnace is almost full and then fed just fast enough to take the place of the iron and slag drawn off from below, the fuel and waste escaping as gas. As the fire consumes the fuel at the bottom and the charge descends it passes through several well-defined zones. Starting at the top unchanged it grows hotter and hotter, the moisture is driven off, until finally the ore is roasted and becomes magnetic oxide of iron, the most favorable condition for reduction. The coke and the flux still remain substantially unchanged, but when the charge reaches the boshes the temperature has risen to the point where the fuel ignites, and the hottest part of the furnace is soon reached. Here the ore is melted and its oxygen driven off. The flux, suited to the character of the ore and planned so that it melts at the same time, coats each little iron globule and prevents it from being immediately oxidized and so carries it safely past the danger zone. Continuing its descent past the tuyères the iron goes to the crucible at the bottom of the hearth, where it accumulates, and the flux being lighter floats on top and protects it

from the oxidizing influence of the blast above. At certain intervals the iron and flux are drawn off through small holes at the bottom of the hearth, the iron being run into the bed and made into pigs and the flux drawn off out of the way and allowed to cool, when it is called "slag," for which a variety of uses has been found.

Since some blast furnaces are as much as 90 feet in height it might seem that the immense weight of the charge would crush down the fire and smother it, but the charge is actually buoyed up by the enormous pressure of the air blast blown in through the tuyères, the weight of the air being literally more than twice the weight of the charge.

A fairly typical blast furnace is Furnace F of the Edgar Thomson Steel Works near Pittsburg. It is 80 feet high, 22 feet in diameter at the boshes, its hearth is 11 feet in diameter, and the furnace has a capacity of 18,000 cubic feet. It produces on an average 351 tons of pig iron per day and burns 1756 pounds of coke for every ton of iron produced. A writer describes the air blast supplying it as follows: —

"Heating the 25,000 cubic feet of air supplied per minute to a temperature of 1200 degrees Fahrenheit, its volume would be increased to 85,000 cubic feet; and on the supposition that the furnace is blown by seven tuyères, each seven inches in diameter, this torrid air would rush through each tuyère (under a pressure of nine pounds per square inch) at the rate of 12,143 cubic feet, and having the enormous lineal velocity of 45,417 feet per minute. This velocity is over five times that of the most violent tornadoes, and the pressure is more than 25 times greater. Should a blast of equal pressure and velocity come from unfathomed space and envelop the earth, it is absolutely certain that no living beings nor loose materials would be left upon its rock ribbed skeleton, which, stripped of its flesh and blood, fields and forests, lakes and oceans, would be hurled

into a new orbit and made to assume revolutions and rotations whose amplitude and duration it is impossible to imagine or describe."

When enough molten iron has accumulated in the hearth a plug of fire clay is knocked out and the metal runs out into a bed of sand through which a main channel is cut, with smaller channels leading off from it at right angles. The smaller channels are known as "sows" and from these branch at right angles a series of short channels known as "pigs," where the iron cools, the cooling being sometimes hastened by a man with a hose, after which it is broken into small pieces and loaded on the cars.

It costs on an average about 20 cents a ton to take care of the iron after leaving the furnace till it is loaded on the cars. A bed of sand has some objectionable features. The silicon in the sand tends to unite somewhat with the melted iron and renders it unsuitable for making the best steel. To overcome this difficulty and to reduce the cost of handling, casting machines are made consisting of a line of connected traveling molds arranged in the form of an endless belt and carried on rollers. The molten iron is drawn from the furnace into great ladles and poured from these into the molds as they come moving past, the size of the stream being just enough to fill the molds as they pass under the ladle. Passing on in their course the molds are carried down a slight incline to a level where the bottoms are brought in contact with the top of the water in a long tank. As they continue their course the track dips more and more until the mold passes entirely beneath the water. The track emerges and rises high enough to allow the pigs of iron to drop into cars ready to receive them at the other end, and as the wet molds travel back under the tank for a fresh charge at the ladle they pass through a gas furnace which dries the molds and deposits on them a coating of soot that prevents the molten iron from sticking to them when they turn

CASTING PIG IRON, BETHLEHEM STEEL WORKS.

up at the ladle to receive another charge. In this machine the only hand labor required is that regulating the flow of iron from the ladle, and the cost of handling the pigs has been reduced from 20 cents to 5 cents a ton.

Pure iron, a curiosity of the laboratory, is of a white silvery color, has a beautiful luster and is very soft and tough. When subjected to heat in the presence of oxygen, it burns long before the melting point is reached, but in the absence of oxygen it fuses at about 3000° Fahrenheit.

Pig iron is iron containing from 1½ per cent. to 7 per cent. of carbon, which renders it brittle and fusible at a comparatively low temperature. Pig iron is made in three varieties: gray, mottle, and white, and is classed in eight grades beginning with gray and ending with white. The gray is coarse, granular, and soft; the white finely crystalline, and as hard as the hardest steel, the difference being due mainly to the different combinations of the carbon in its make-up. Pig iron fuses at from 1922° to 2192° Fahrenheit, according to its grade, and its average chemical composition is about as follows: —

Combined Carbon	0.91 per cent.
Graphitic Carbon	1.92 per cent.
Silicon	1.81 per cent.
Phosphorus	.33 per cent.
Sulphur,	.25 per cent.
Manganese	1.28 per cent.
Pure Iron	93.50 per cent.
	100.00 per cent.

Cast iron is practically the same as pig iron except that it has been reheated and cast into the desired form. If hammered cold it breaks and cannot be welded like wrought iron. Malleable iron is cast iron, made by puddling or boiling and hammering or squeezing, thus getting rid of some of the impurities, until it can be hammered cold without cracking.

Puddling is the process of ridding the pig iron of some of its impurities and superfluous carbon by melting it in a reverberatory furnace and forcing through it a blast of hot air, and at the same time stirring the molten fluid. By this operation a large part of the carbon that rendered the metal brittle is burned out and the particles of iron have enough cohesion so that they can be formed into balls and squeezed in machinery or into blooms (bars or ingots) and hammered. This product when remelted and cast will stand considerable hammering when cold without cracking.

Wrought iron is made by the same process only the puddling is stopped sooner and the working carried farther. It contains less silicon and carbon than cast iron, but more of these substances than malleable iron. Wrought iron fuses at from 2732° to 2912° Fahrenheit, but before reaching the point of fusion becomes white and pasty, and when two pieces of iron in this condition are brought in contact, the surfaces adhere and the masses can be united, forming a "weld." It is this property of welding that renders wrought iron so valuable in the arts. The phosphorus and sulphur, undesirable substances within the iron, cannot be burned out without burning the iron, and as silicon melts at a less heat than the iron, the mass is heated to the melting point of silicon and rolled, hammered, and squeezed, when, under the influence of pressure, the liquid silicon, phosphorus and sulphur unite and are squeezed out of the iron in the form of cinder or slag, the working being continued until the desired degree of purity has been reached.

The methods by which wrought iron is produced from pig iron are chiefly the inventions of Henry Cort of England, who, in 1783-84, introduced puddling grooved rolls to take the place of hammering and the reverberatory furnace. He first melted his iron and caused the fierce flame of the furnace to pass over the iron, the flame in its course being bent back by the roof of the furnace (reverberated) and

passing over the face of the molten metal burned out the carbon and reduced the necessary amount of working. Rogers introduced a cast iron bed cooled by air instead of the sand bed used by Cort. Neilson of Glasgow in 1828 took out a patent for heating the air blast before introducing it into the furnace and by this method greatly increased the furnace capacity. Neilson's method was used at first wholly for the manufacture of pig iron, but probably gave a hint to Kelly, Bessemer, Mushet and Siemens.

Steel means more than any other metal to modern progress, for it enters into nearly every manufactured product, either as a component part or in the construction of the machine which produced it. Articles with the widest difference in size, shape, and uses are made from it, ranging from the finest cambric needle or the hair-spring of a watch to the armor of a battleship or the largest cannon, yet it is only the last quarter century that has seen the introduction of steel for articles of any considerable weight. Steel was known at an early age and the sword plates of Damascus were famous before the birth of Christ, while the steel of India, "wootz," is almost as famous and perhaps as old. Although the steel maker of the present is not able to produce any better steel in small quantities than his early progenitor, and in fact finds it difficult to equal him, yet he is able to make it in such large quantities of uniform quality that it rivals iron in cheapness and far exceeds it in strength and rigidity.

Steel is a peculiar metal in composition, lying about midway between cast and malleable iron. It contains less silicon, sulphur, and phosphorus than either, and its carbon is present in a definitely known proportion ranging from ¼ per cent. to 2½ per cent., the carbon rendering it hard and brittle. Steel fuses at from 2372° to 2552° Fahrenheit, dependent upon the amount of carbon it contains. Steel possesses the peculiar property of tempering, that is, its condition of crystallization can be set in several forms by heating the

steel to a certain temperature and then suddenly cooling it. It is this property of tempering that makes it possible to give steel almost any degree of hardness and renders it fit for springs and tools with cutting edges. The ancients are said to have possessed the secret of tempering copper, now considered as one of the lost arts. When the steel is heated there is formed on its surface an oxide of iron, the color of which is a sure index to the temperature to which the steel has been raised.

"**The effects of temper** vary with the nature of the steel, and are much more pronounced, as the steel is more carbonized and homogeneous. The increase of resistance produced by oil temper varies from 79 to 12 per cent., according to Kirkaldy,—a very high authority,—in the case of high steels tempered at a high temperature and low steels tempered at a medium temperature. Oil temper increases the homogeneity of medium steel by destroying the crystalline texture which the latter frequently presents in the central parts of specimens, and increases its resistance to percussion.

"The following table, from tests made by the Navy Department, will give an idea of the effect of oil temper on the physical properties of mild or medium hard steel, for example:—

ELASTIC STRENGTH		TENSILE STRENGTH		ELONGATION	
Before tempering Tons	After tempering Tons	Before tempering Tons	After tempering Tons	Before tempering Tons	After tempering Tons
13	29.2	26.8	45.2	.737	.433
13	27.8	27.8	46.0	.707	.345
12	26.0	27.6	39.6	.713	.420
12	25.8	28.0	41.0	.633	.480
13.77	34.15	28.11	49.8	.596	.260
12.18	34.8	26.9	49.4	.564	.202

"Thus it will be seen that the elastic strength is more than doubled, the tensile strength raised more than 60 per cent., while the elongation is reduced over 40 per cent.

"**The annealing process reduces** the tensile and elastic strength from 10 to 15 per cent., and restores the ductility, as measured by the elongation, from 25 to 40 per cent." *

Another method of tempering steel is to melt alloys which fuse at a known temperature, then plunge the steel into the melted mass. The following table shows the color and temperature of steel for different tempers and the proportions of lead and tin that would melt at the temperature required to give steel dipped in it the right temper.

TEMPER	TEMPERATURE	ALLOY
Pale straw	420° Fahrenheit	7 lead to 4 tin
Straw	450° "	8 " " 4 "
Straw yellow	480° "	8½ " " 4 "
Nut brown	500° "	14 " " 4 "
Purple	530° "	19 " " 4 "
Bright blue	580° "	48 " " 4 "
Deep blue	590° "	50 " " 2 "
Blackish blue	640° "	All lead

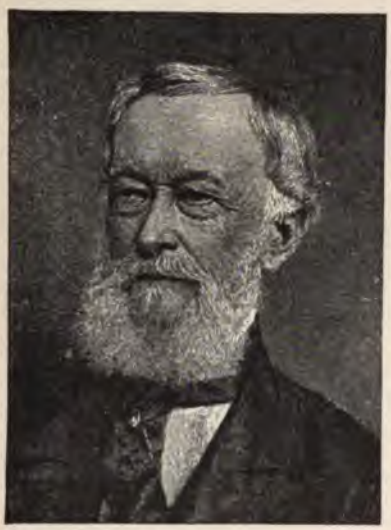
The constitution of iron and steel is clearly shown by dissolving each in chlorine gas. Chlorine unites readily with the iron, but does not affect the slag, so dissolves out pure iron leaving a skeleton of slag in exactly the position it had occupied in the iron, sometimes showing the slag to be grouped in such a way as to materially weaken the iron. A piece of steel so treated will leave no skeleton, the slag showing only in a small amount of sediment.

The crucible process of making steel is the oldest of the modern methods, for it consists simply in melting wrought iron in the presence of carbon in crucibles, and it was in this way that the Indian "wootz" was made. The melting point of wrought iron is so high that it was difficult to reach in the early furnaces, so steel was ordinarily made by heating wrought iron in a furnace with charcoal, the heated metal taking up carbon enough from the charcoal to form

* Ingersoll's "Text-Book of Ordnance and Gunnery."

steel. This method was known as "carburizing" or "cementation," and the steel was called "blistered bar" and formed the steel of commerce until about 1770, when Huntsman succeeded in melting it in a crucible and produced cast steel.

Prior to 1855 cast steel was made entirely by the crucible process, and Krupp, the famous gun maker of Essen, Germany, was the largest producer. The difficulties connected with this method were great, for only about 90 pounds of steel could be made in one crucible and many crucibles had to be used in making a casting of large size. If a crucible were poured before it were quite ready, the steel would not have the right composition, and if held over a few minutes the steel would be burnt. This meant that all the crucibles must be ready to pour at the same instant. Difficult as was the process, Krupp brought it to such a high state of perfection that in 1851 he showed an ingot weighing about 5000 pounds at the London Exhibition; and in 1873, at Vienna, he displayed a similar ingot made by the crucible method, which weighed 115,000 pounds. However, it is exceedingly doubtful if Krupp's ingots were without flaws for in 1857 Sir William Armstrong was unable to find a perfect ingot of only 350 pounds weight from which to make a cannon.



ALFRED FRIEDRICH KRUPP.

The Bessemer process of steel making consists of forcing a blast of air through a crucible (converter) containing melted cast iron, and so burning out the excess of carbon and making the cast iron directly into steel. In 1855–56 Sir Henry Bessemer took out pat-

ents in England for a process of changing cast iron directly into steel by blowing atmospheric air through the molten metal. In 1856 he secured two patents in the United States but was immediately confronted by the claim of priority of William Kelly, an iron maker of Eddyville, Kentucky, who was granted a patent in interference which operated as a bar to the patents granted Bessemer. Kelly showed that as early as 1847 he had experimented with air blasts and had produced the wrought iron from cast iron. Kelly had not made steel and Bessemer was not successful until reinforced by the discoveries of Mushet and Göransson.

Sir Henry Bessemer.

"**Robert F. Mushet,** after Bessemer's process had failed in 1855–56 to successfully manufacture the steel, took out a patent September, 1856, for a process of adding to melted cast iron which had been decarbonized and desiliconized by a pneumatic blast a triple compound of carbon, iron, and manganese, and the addition of from 1 per cent. to 5 per cent. of this compound to the cast iron mentioned at once overcame the obstacle which had been fatal to the success of Mr. Bessemer. Bessemer had decarbonized and desiliconized melted cast iron but he had not been able to retain or restore the small quantity of carbon that was necessary to produce steel, and in the oxygen of his powerful blast he had given to the contents of his converter an element which prevented the production of even good iron. Mr. Mushet's invention regulated the supply of carbon and eliminated the oxygen."*

Mushet's British patents lapsed, and became public property, owing to his poverty and other unfortunte circumstances.

* Swank. "Iron in All Ages."

Neither Kelly, to whom a broad United States patent was issued covering the idea of forcing air through molten iron, nor Bessemer, was able to produce good steel without the aid of Mushet's discovery, and yet the latter died poor and unknown while Bessemer was knighted by Queen Victoria for his invention and received royalties aggregating $500,000 a year. He acknowledged some moral obligation to Mushet by allowing him an annuity of £300.

In 1890, at the international meeting of the Iron and Steel Institute of Great Britain, Verein deutscher Eisenbuttenleute, and the American Institute of Mining Engineers, Sir James Kitson, president of the Institute, read a letter from Sir Henry Bessemer giving a description of the process, but Bessemer did not even mention Mushet's name.

But even with Mushet's improvement, only iron ore that was practically free from phosphorus could be used for making Bessemer steel. Two English chemists, Sidney Gilchrist Thomas and Percy C. Gilchrist, took out a patent November, 1877, for a lining of a Bessemer converter made from a mixture of calcined dolomite and tar. This lining neutralized the phosphorus in the iron and made it possible to make good steel out of ores that were before considered unfit. These latter linings are called "basic" in contrast with the older "acid" linings. In the United States patents for a process of dephosphorizing iron were issued to Reese of Pittsburg in 1866, and as the process covered by the patents of Kelly, Mushet, Bessemer, Reese, and Thomas and Gilchrist were all necessary for the profitable manufacture of steel in America, they were finally consolidated and became the property of stock companies; the consolidation resulting in a large reduction of fees and royalties, the business of making Bessemer steel in the United States progressed with great rapidity.

The method now known as the Bessemer process uses a huge steel flask called a "converter" made from steel plates lined with

some refractory material perhaps a foot thick, the flask having a capacity from eight to twelve times as great as the charge it is to contain so as to allow the metal to boil. The flask swings on trunnions like a cannon and is fitted on the sides with a rack and pinion gearing, by which it can be tipped at any angle, while in the bottom are numerous holes through which blasts of air are driven into the molten metal. The pig iron, melted in a blast furnace, is drawn off into a large ladle and poured into the converter. The air blast is then turned on and the oxygen in the blast uniting with the silicon and carbon in the iron, the mass bubbles and boils furiously and rises to such a heat as to easily melt an additional 10 per cent. of scrap iron. When the silicon burns the flame from the mouth of the flask is rather dull, but when the carbon is given off the flame increases in brilliancy and becomes an intense white roaring blaze, the seething metal dashing about, shaking the flask and its foundations. As the carbon burns out the flame goes down, and this is the critical moment, for a mistake of a few seconds may ruin the charge because the right amount of carbon for the steel is contained within the charge of spiegeleisen and it is necessary to burn out all the carbon that was in the pig iron before the spiegeleisen is introduced. When the proper moment has arrived the spiegeleisen is added, the blast shut off, the converter given a few mighty shakes to thoroughly mix the contents, and the entire charge poured out into a great ladle, from which it is run into molds and cast into ingots.

The usual charge of a Bessemer converter is eight tons, so the process is not practicable for the production of larger castings owing to the mechanical difficulties in the way of bringing two or more converters to readiness for pouring at the same instant. However, it is the method most used for the manufacture of steel rails and structural steel, and it requires great skill, for if the blast is shut off too soon imperfect steel is produced, and if continued too long

the metal is burnt and the charge rendered useless. As the entire time taken in a single blast is not over thirty minutes, an error of a few seconds is enough to spoil tons of steel.

Although since Bessemer's invention great improvements have been made in the art of steel making, he is justly regarded as a pioneer and "benefactor of his kind," for as his method went into general use it seemed as though new blood had been infused into the arteries of the world's trade. Larger engines were made, steel rails became practicable, stronger and better ships were made. Steel entered generally into the structure of buildings, making them larger, lighter, cheaper, better, and rendering the ground on which they stood more valuable. In whatever line steel had been used it was now available at a less price, a boon to all. It is impossible to conceive the number of accidents averted and the human suffering saved by using it with its greater strength in the place of iron.

The open-hearth or Siemens-Martin process is the one now usually employed for making the largest steel castings. Charles William and Frederick Siemens, natives of Hanover but residents of England, took out in 1856 patents for a furnace where gas was employed instead of the direct heat of the fuel and in 1861 made cast steel by the aid of the furnace. About the same time Emile and Martin of France took out various patents for inventions which were applicable to the manufacture of steel by the Siemens furnace. The open-hearth process did not originate either with Siemens or the Martins, for Heath and others, as early as 1845, had made steel in a similar manner, but it was the invention of the gas furnace by Siemens that made the process profitable.

The open-hearth process has an advantage over the Bessemer process in that it can keep the melted mixture indefinitely until experiments with test portions determine the exact quality of the steel; its installation is more economical and it also uses up the scrap steel

and rail ends which accumulate at a Bessemer furnace, and can use worn out steel rails. It is estimated that in the first 35 years of their operation the Bessemer and open-hearth processes increased the production of steel more than a hundredfold.

The open-hearth method introduced into the United States in 1868 is the method now used in making castings of almost unlimited size, for the capacity of the furnace is practically unlimited and the product of several may be turned into one mold. The open-hearth furnace is a large fire brick structure, near the top of which is the "bed" or "container" for the metal. Below this, on each side of the furnace, are two perforated checkerwork walls of fire brick, through one of which hot air is forced and through the other, gas. The furnace is heated by forcing in the air and gas and igniting them above the bed or container. The products of combustion are drawn out through the checkerwork at the other side of the furnace, heating it, as they pass, to a high temperature. After the current has passed in one direction for twenty minutes it is reversed. The gas and air, passing between fire brick just heated by the other current, arrive at the furnace at such a high temperature that a great saving of fuel is made. The gases from this combustion are carried through the checkerwork on side number one and heat it up by the time side number two has become cool. This reversal of current is made every twenty minutes throughout the entire "heat," which lasts from twelve to fourteen hours.

The charging of the furnace is done by a special machine usually operated by electricity. The one at the plant of the Bethlehem Steel Company picks up with a twenty-foot arm a box containing 7000 pounds of charging material and holding it "at arm's length" carries it into the furnace, empties it, and withdraws the box with no apparent effort. The charge is made up of scrap iron, scrap steel, pig iron, and ore in proportions that will secure the exact chemical

composition desired. Six or eight hours are required to melt the charge and from four to six more to reduce it to the right condition for pouring. During this latter period samples are taken out at frequent intervals and analyzed. By this means the exact condition can be known and the process watched step by step, rendering the result more certain than other more or less "guess-at-it" methods, while the longer time taken lessens the chance of error.

Large steel castings successfully produced represent so many difficult problems solved that they may well be considered triumphs of the steel maker's art. When molten steel is poured into a mold several difficulties have to be overcome to obtain a perfect casting. The worst are called piping, blow-holes, surface cracks, internal cracks, and segregation. Piping is well illustrated by the freezing of water in a tumbler, the ice beginning to form on the outside, the particles drawing away from the center and leaving it hollow. The same thing occurs in the mold when steel is changing from a liquid to a solid state, except that steel begins to solidify at about 2500° Fahrenheit. As it cools at the outside of the mold it contracts and tends to draw the material away from the center and unless this is prevented, instead of having a solid ingot one will form with a hole in the center perhaps running from end to end. This defect is called a "piping."

Segregation is the tendency of the steel to squeeze out the other constituents as it cools. These, being lighter in weight than the iron, collect in the pipe or float on the top, and of course with the alloys squeezed out the steel is inferior.

Irregularities in cooling set up such stresses that cracks often occur on the surface, or, more deceptive and dangerous yet, internally, just as wood checks in seasoning. When the molten metal is poured into the mold air is carried with it and during the cooling gases are formed which tend to produce cavities or blow-holes. Sub-

ARMOR PLATE INGOT.

Showing a nickel steel armor plate ingot cast for the port plate of U. S. battle ship *Iowa*. Manufactured by the Bethlehem Steel Company.

jecting the metal to an enormous pressure while it is in a molten condition seems to be the most successful method of overcoming these difficulties.

When the metal is ready to pour, a fire-clay plug in the bottom of the furnace is knocked out and the metal run into a huge ladle or car which carries it to the mold. A casting for a large gun contains almost twice as much metal as appears in the finished product. The extra amount is to allow for compression, forging, machining, and enough extra length for test pieces.

The mold is built up of large, strong steel rings, placed one above the other, firmly bolted together and placed on a firm base mounted on wheels so that it can be moved about. The mold is heated, the ladle swung over it and the molten metal poured into it with such precautions as will to some extent prevent the formation of "blow-holes." Next the mold with its load of metal is placed under a monster press and the "Whitworth Fluid Compression" process begins. At the Bethlehem Steel Works a press with an upper head weighing 135 tons, a lower head weighing 125 tons, and capable of exerting a pressure of 7000 tons is used for this purpose. Under this enormous pressure air bubbles are forced out, blow-holes cannot form, piping cannot occur, and segregation is reduced to a minimum. This pressure is kept up until the ingot has solidified, and as a result gives a solid, flawless mass of steel which maintains the intended chemical composition.

The steam hammer and hydraulic press play important parts in the manufacture of steel, but the hammer is being rapidly driven out of business by the press. As recently as 1891 the Bethlehem Steel Company built the largest steam hammer in the world, standing 70 feet above the floor, the hammer head, weighing 125 tons and having a stroke of 20 feet, falling upon an anvil of metal which weighed 2150 pounds, and yet the progress of a single decade has rendered obsolete this $1,000,000 hammer.

Figure 1 shows the result of hammering a piece of steel. Only the surface is worked and is longer than the center, producing a V-shaped end. This sets up strains within and may even split or tear loose from the center, rendering the piece useless. Again, working only the surface does not develop the strength of the interior and produces an inferior article.

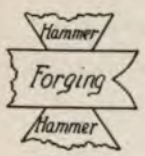


Fig. 1.

Figure 2 shows the result produced by using a steady pressure which causes the metal to "flow" and bulge out in the center, thus showing that the entire thickness of the forging is acted upon by the pressure.

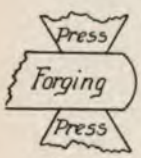


Fig. 2.

The piping and segregation, likely to occur in large ingots, are now removed whenever possible by boring a hole through them and making them into hollow forgings. A shaft in this way can be decreased 25 per cent. in weight and the material improved so much in quality that the loss of strength will be only about 6 per cent., and this is the method commonly employed for propeller shafts for steamships.

Large shafts must be reheated many times before the forging is completed, and as each reheating may take from two to three days, a saving of time is no small item. Reference to Figure 3 shows that the distance from *c* to *d* is less than half the distance from *a* to *b*. By boring out the center a greater surface is exposed to the heat and less than half the thickness of metal has to be heated, so a saving of time and fuel is effected. When large, solid forgings are heated the surface metal expands faster than the core and sometimes cracks loose from it; in cooling, the outside contracts faster than the core and sometimes cracks on the surface. These troubles are obviated by removing the core.

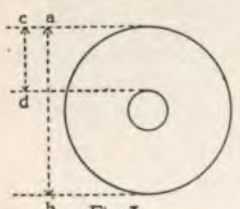


Fig. 3.

Annealing. If a steel ingot is cooled slowly from the point where it begins to get solid the temperature falls to between 1200 and 1300° Fahrenheit and there remains stationary for a time. This point is known as the recalescent point, and chemical and physical tests show that a change in the physical structure of the steel occurs at that point and there the process of crystallization seems to come to a halt. Now if the steel be heated to any point below the recalescent point the crystallization will not be changed. If the steel be allowed to cool slowly, it forms large crystals, and if it then be heated above the recalescent point the crystallization will be found smaller than before. Now since the temperature can wholly change the crystallization of a piece of steel it is plain that heat bears an important part in manufacture. When steel is suddenly heated and put under the hammer or press and forged the crystals are driven about and made to assume positions not natural to them and, when cooled quickly, internal strains are set up, greatly reducing the strength of the material. If the forging then be heated slowly and allowed to cool slowly it gives the particles within a chance to rearrange and adapt themselves to their new environment and relieves the piece of these strains. After annealing the forging can again be heated and tempered, for it is not necessary to raise it to a high temperature to temper it.

Alloys. The tensile strength of a piece of metal is the pull or tension required to break it. The elastic limit is the pull it will endure without permanently stretching. Nickel as an alloy increases the elastic limit more than it does the tensile strength, that is, in a good grade of common steel the elastic limit would be about 47 per cent. of the tensile strength, but in the propeller shafts of the cruiser *Brooklyn*, where nickel steel was employed, the elastic limit is 63 per cent. on a tensile strength of 93,000 pounds per square inch. Later improvements have been made and now the tensile strength of

propeller shafts for torpedo boats frequently runs over 100,000 pounds per square inch, with an elastic limit 68 per cent. of the tensile strength. It is because nickel added to steel increases its tensile limit that nickel-steel armor is able to withstand the heavy shocks of the projectiles from powerful guns without breaking, whereas ordinary steel as hard but not having the same toughness would crack and break up.

Chromium and tungsten in moderate amounts are used as alloys with steel, to impart special hardening properties, rendering it useful for cutting tools and for armor-piercing projectiles. Manganese in any considerable quantity makes steel so remarkably tough and hard as to render machining impracticable. Aluminum seems to increase the fluidity of steel and aids in preventing the formation of blow-holes in castings. Much attention has been given to alloys and many patents issued covering them.

Testing Steel. Before a large quantity of steel is accepted by any important manufacturing plant one or more pieces from each batch of steel are taken out and subjected to certain tests and if they do not come up to the standard the whole batch is rejected. It is important to know just how much stress any material will stand without changing its form. Engineers call this the elastic limit, and if the elastic limit is exceeded the steel changes its shape, becomes weakened, and never returns to its original form. Usually the test pieces are about two inches long and one half inch square at the part to be tested, the ends being left larger so as to afford a good grip for the jaws of the testing machine. The test piece is cut out the full size and then *machined* down in the middle instead of forging, for if it were forged there would be more work done and it would not show the true quality of the mass it was supposed to represent. The testing machines as now built record accurately a pull or a push as the case may be, ranging from a fraction of an ounce to millions

of pounds. The test piece is placed in the jaws of the machine and the force gradually applied until the piece begins to stretch. This should require from 29,000 to 60,000 pounds per square inch in good steel. More force is applied until the piece is drawn out and broken and for this a force of from 58,000 to 90,000 pounds should be required. The variation is due to the fact that there are many kinds of steel each with characteristics of its own. As a rule the poorer grades stretch most, but even the better ones will stretch 22 per cent. before breaking. The broken ends are examined with a microscope, the hardness tested, a chemical analysis made and the exact proportion of each ingredient found out.

The testing machine made for the government by A. H. Emery is probably the most accurate in the world. It is employed at the Watertown Arsenal and can exert a pressure of more than 1,000,000 pounds or a pull of more than 800,000 pounds. The machine will test a bar 31 feet long for compression and 37 feet 3 inches long for tensile strength. The ram or straining cylinder is 20 inches in diameter and has a 24-inch stroke. The Union Bridge Company of Athens, Pa., has one with a capacity of 1,224,000 pounds that can break a bar 40 feet long, while the Phœnix Bridge Company of Phœnixville, Pa., has one with a capacity of 2,160,000 that can break a bar 45 feet long. Smaller testing machines of the same type are used elsewhere, and many other varieties, but the Emery is recognized as having no superiors. Its accuracy is so generally recognized that the large manufacturing establishments constantly compare their machines with that at the Watertown Arsenal, just as a man compares his watch with a chronometer. The machine itself is too complicated to be described within the limits of this article, but the stresses are produced by a movable ram. If great force is required, the ram is operated by hydraulic pressure; if the strain is to be a light one, screw power is used. Great force is sometimes necessary

for small pieces, as wire, small rods, etc., show a higher tensile strength than the same material in larger pieces. A link of iron 5 inches in diameter was broken with a stress of 36,000 pounds per square inch. The same metal in the form of an inch bar required 60,000 pounds to break it, hence the very obvious necessity of having a machine strong enough to break large pieces.

Enormous as is the strength of the Emery machine, its delicacy is no less amazing. It can exert a compressing force of 1,000,000 pounds and the next minute crack egg shells and nuts placed between its jaws. It can pull in two an iron bar 5 inches in diameter and immediately after measure the force required to break a horse hair and show how much the hair stretches before it breaks. If a violin string be attached and strained until it gives a musical tone it will measure the exact amount of force required to change its pitch.

The specifications for every important building, bridge, or machine nowadays constructed state tests which the materials must undergo. The efficiency of the structure and the safety of the public demand that these tests be carefully and accurately made and that materials be able to support much greater loads than are likely to be placed upon them in actual service. The weight of a bridge across a stream, the pressure of the wind, and the weight of the loads the bridge must sustain can be pretty accurately estimated. Plans can then be drawn for a bridge of certain dimensions, requiring materials to stand tests that give a margin of safety. In building a cannon the weight of the projectile and the force of the powder charge can be accurately determined and, if the strength of the materials be known, a gun produced that can be safely used. It was the necessity for accurate information of this kind that brought out the various testing machines which have culminated in that of Emery.

Taylor-White Tool Steel. An important gain in the working

of metals was lately made at Bethlehem, Pa., because the forge department of the Bethlehem Steel Company exceeded in capacity the shop where the forgings were finished. An enlargement of the shop, likely to cost a million or more dollars, seemed necessary. Before spending the money, however, it was decided to make experiments to see if the capacity of the shop could not be increased by improving the tools. It was while experimenting on the tools used in the lathes that Messrs. Taylor and White made their important discovery that steel of a special composition could be so tempered that it would retain its cutting edge at a temperature twice as high as the limit of steel from which tools are usually made. Ordinarily, steel loses its temper for cutting purposes at about 500° Fahrenheit but the Taylor-White steel holds its temper up to 1100 or 1200 degrees and will actually work in the lathe cutting good smooth chips after the friction of the work has raised the tool to a dull red heat. The gain was evident. Where they formerly cut 8 feet 11 inches a minute they can now cut more than 25 feet, increasing also the depth and the width of the cut. The number of pounds of metal removed per hour averaged under the old process in October, 1898, 31.18 pounds per tool; in May, 1899, with new process, 81.52 pounds per tool; in January, 1900, 137.3 pounds per tool. The cutting speed had been raised 183 per cent. and the metal removed increased 340 per cent. The line shafts of the shop that formerly ran at 90 revolutions per minute were speeded up to 250 revolutions per minute, and the forge was pushed to its utmost capacity to keep the shop supplied with forgings. The $1,000,000 addition contemplated had been saved but in the experiments more than 200 tons of steel forgings had been cut into chips, with an expenditure for material and labor of over $100,000.

The Taylor-White tool steel is softer than that of other self-hardening steels, and 4-inch bars can be successfully treated by the proc-

ess. The same process improves Mushet and other self-hardening steels but not in the same proportion that it does the special composition of the Taylor-White steel.

The use of iron was unknown to the inhabitants of America prior to the discovery of the continent by the white man. The inhabitants of Mexico and Peru who were most advanced in the arts of civilization used copper as a substitute, while among the North American Indians, stone was used. Archæologists have found in the ancient mounds of Ohio masses of meteoric iron from which implements and ornaments were made by hammering, and the Greenland Eskimos made knives and other weapons from native ore found in Greenland, but always by hammering, not by melting and casting. The first iron ore discovered in America was that found by an expedition to North Carolina in 1585 fitted out by Sir Walter Raleigh to make a settlement at Roanoke. Hariot, the historian of the colony, says, "The ground by rockie which by the triall of a minerall man was founde to hold iron richly. It is founde in manie places of the countrey else." But Raleigh's colonists were in search of gold and were not interested in iron.

The records of the colony at Jamestown, Virginia, show that in 1608 Captain Newport "sailed from Jamestown with a cargo of iron ore, sassafras, cedar posts, and walnut boards." Skilled workmen were sent to the Virginia colony and the construction of a furnace was begun, but the foreman died and the others were killed off by the Indians. No further attempt to manufacture iron appears to have been made there for almost a hundred years, but in the next century Virginia became prominent in the manufacture of iron.

The first successful iron works in America were established near Lynn, Massachusetts. "In 1643 Mr. John Winthrop came from England with workmen and stock to the amount of £1000 for commencing the work. A foundry was erected on the western bank of

the Saugus river." This was near Lynn, and it was the first iron foundry established in America. The first iron article made from native iron ore in America was cast here in 1645. It was an iron pot weighing two pounds thirteen ounces, and holding a little less than one quart.

First Iron Article Manufactured in America.

A furnace built at Middleboro, Mass., in 1758, was operated for many years and is said to have cast shot used in two wars, furnishing those for the *Constitution* in her conflict with the *Guerrière*.

The first iron foundry at Pittsburg was built about 1805 on the site of the present post office. In 1812 it was turned into a cannon foundry for the general government, making shot, howitzers, and cannon. This foundry is credited with having furnished the supplies for Perry's fleet on Lake Erie and Jackson's army at New Orleans.

William Penn encouraged the manufacture of iron in his colony, where it was produced at least as early as 1692, and Pennsylvania soon achieved the prominent place in the iron industry which she has since so ably maintained.

For some reason ironmasters and their descendants played a very prominent part in the history of the new country. Washington's father was interested in iron furnaces in Maryland and Virginia. Lincoln was descended from Mordecai Lincoln, an ironmaster of Scituate, Mass. Franklin, if not directly interested in the manufacture of iron, at least had friends who were, and the celebrated stove invented by him in 1792 was cast at the Warwick furnace on French Creek, nineteen miles from Reading. The same foundry was afterward active in casting cannon.

Ethan Allen was also interested in the manufacture of iron, and Generals Greene and Morgan were the sons of ironmasters, while several of the signers of the Declaration of Independence were connected with some branch of the industry. One of them, George

Taylor, born in Ireland, was so poor that to get to America he was obliged to sell his services and go as a "redemptioner." He afterward worked in a most humble capacity in an iron furnace, yet became, himself, an ironmaster and a man of wide influence. Ericsson owed no small part of his success with the *Monitor* to the support given him by his financial backers, John A. Griswold and John A. Winslow. There can be no reasonable doubt that the executive ability required to manage the great iron and steel manufacturing establishments of to-day could achieve distinction in the political field.

The first iron works in Canada were established at St. Maurice near Three Rivers in the province of Quebec. Count Frontenac in 1667 discovered iron ore and in 1672 reported that he had commenced to mine it at Three Rivers for export to France. He strongly urged the development of the mines and the establishment of furnaces and foundries. "King Louis XV. gave a royal license in 1730 to a company to work the iron ores of St. Maurice and the vicinity, and advanced 10,000 livres for aid in erecting the furnace, etc. No work being done, he took back the license and in 1735 granted it to a new company, which received 100,000 livres in aid and in 1737 built a blast furnace. In 1743, however, the works reverted to the crown and were worked for the king's profit." *

The St. Maurice works continued in active operation until 1760, when Canada passed into the possession of the British government. Then for nearly a hundred years the crown leased the works to various companies. They were finally closed in 1883 because the ore and fuel had become exhausted. But the St. Maurice furnace, erected in 1737 and closed in 1883, had the *longest record of service of any on the American continent.*

Canada is rich in ore deposits and is rapidly developing her mineral resources which she has wisely fostered by government aid.

* Dr. T. Sterry Hunt.

"The bounty act of June 29, 1897, provides that premiums shall be paid on iron and steel products as follows: "On steel ingots puddled into bars and pig iron a bonus of $3 per ton is to be paid, provided at least 50 per cent. of the steel product is made from Canadian pig iron. On steel ingots and derived product not made from Canadian pig iron, a bonus of $2 per ton is paid. The act of August 11, 1899, extended the bounty to June 30, 1907, but at a diminishing rate of premium as follows: After June 30, 1903, the above premiums will be paid on only 90 per cent. of the respective products, and for each successive year on a smaller per cent. of the output, namely, on 75 per cent., 55 per cent., 35 per cent., and 20 per cent., ending with June 30, 1907. By that time presumably the experimental stage of production will have ended and the industry will be on a self-sustaining basis." *

In less than a quarter of a century the output of pig iron in Canada has increased more than 25 fold. In 1892 Canada exported three tons of iron valued at $95; in 1899, more than 2000 tons valued at more than $50,000. The United States takes about three fifths of Canada's export. The following table shows the output of Canadian pig iron from 1876 to 1899, the amount exported and its value from 1892 to 1899. The stimulus of the bounty in 1897 is apparent:—

Year	Tons produced	Year	Tons produced	Tons exported	Value
1876	4,000	1888	22,209		
1877	13,500	1889	24,823		
1878	16,000	1890	25,697		
1879	16,500	1891	20,153		
1880	23,000	1892	30,294	3	$95
1881	18,500	1893	46,948	12	330
1882	21,500	1894	62,522		
1883	32,000	1895	31,692	259	6,202
1884	29,389	1896	52,052	1,940	45,363
1885	25,770	1897	33,254	2,627	65,555
1886	26,180	1898	75,920	2,403	61,029
1887	39,717	1899	100,926	2,188	50,767

* *Commerce and Finance*

The ore beds of Newfoundland are wonderfully rich in red hematite, the Wabana beds being 3 miles long, several hundred feet wide, and with about 35,000,000 tons in sight (1901), while their proximity to tide water and ease of working renders them dangerous competitors for mines not so advantageously situated. The ore can be taken from the mines and placed on board ship for about 25 cents per ton, the freight to Canada 25 cents more; to Europe or the United States, only 50 cents per ton. Germany and the United States are extensive purchasers of Newfoundland ore.

Russia has almost boundless deposits of iron ore that are practically untouched, but as they lie so far from the seaports and her transportation system is so poorly developed, she is not likely for many years to become a serious competitor of the leading nations.

In the following table the first column gives the decades of the nineteenth century, the second the population of the United States for the corresponding decades, the third the approximate production of pig iron, the fourth the average number of persons to each ton produced.

Year	Population	Tons of Iron Produced	Inhabitants per Ton
1810	7,240,000	54,000	134
1820	9,655,000	20,000	483
1830	12,866,000	165,000	78
1840	17,063,000	315,000	54
1850	23,192,000	565,000	41
1860	31,443,000	900,000	35
1870	38,558,000	1,865,000	21
1880	50,156,000	4,295,000	12
1890	62,481,000	9,202,703	7
1900	76,295,220	13,620,703*	6†

In 1810 only one ton of iron was produced for every 134 people; at the close of the century more than a ton was produced for every

* 1899. † *Commerce and Finance.*

6 inhabitants, and as but comparatively little of it was exported as raw material practically all of it was used to improve means of communication or transportation, or entered as finished products into the industrial life of the nation. It is safe to say the value of the iron, steel, and articles manufactured from them for a single year exceeds the entire wealth of the country at the beginning of the nineteenth century.

The production and consumption of iron bear a close relation to the prosperity and wealth of a country, for with these is indissolubly linked the transportation system and its manufacturing and agricultural interests. The United States has risen within a quarter century from a comparatively low position in the iron industry to the greatest iron producing country in the world. But a short time ago articles of iron manufacture played but a small part in her exports; now they constitute more than 50 per cent. of the manufactured articles exported. Her locomotives wake the echoes in the Highlands of Scotland, the steppes of Russia, the forests of Brazil, and the land of the Pharaohs. American typewriters go to every civilized country on earth and markets for manufactured goods that were supposed to have been controlled by the older countries are now witnessing the advent of American manufactures. Improved machinery, economy in methods, and great organizations have increased so immensely the production of the United States that the home markets are no longer sufficient, and American goods are now knocking at the doors of all the markets of the world.

The following table shows by tons the pig iron production of the five leading countries of the world. Has it no significance that the production of France, like its population, shows but little increase, while that of her rival, Germany, progresses by leaps and bounds?

	United States	Great Britain	Germany	France	Russia
0	1,665,179	5,963,515	1,391,124	1,178,114	359,531
5	2,023,733	6,365,462	2,029,389	1,448,272	427,182
0	3,835,191	7,749,233	2,729,038	1,725,293	448,411
5	4,044,526	7,415,469	3,687,434	1,630,648	527,536
0	9,202,703	7,904,214	4,658,451	1,962,196	926,482
5	9,446,308	7,703,459	5,465,414	2,003,868	1,452,380
6	8,623,127	8,659,681	6,372,575	2,339,537	1,612,069
7	9,652,680	8,796,465	6,881,466	2,484,191	1,868,671
8	11,773,934	8,609,719	7,312,766	2,525,075	2,222,469
9	13,620,703	9,305,319	8,142,017	2,567,388	2,672,492 *

England has done more than any other country to bring to its present high state of perfection the iron industry. An able authority credits her as follows: —

"**The whole world is indebted to England and Scotland** for the inventions which gave a fresh impetus to the manufacture of iron in the eighteenth century. Payne and Hanbury, who first succeeded in rolling sheet iron; Darby, who first successfully and continuously used coke in the blast furnace; Huntsman, who invented the process of making steel in crucibles; Smeaton, who invented cast iron blowing cylinders; and Cort, who invented grooved rolls and the puddling furnace, were Englishmen; while Watt, who perfected the steam engine, was a Scotchman. It is also indebted to the same countries for most of the inventions of the present century which have further developed the manufacture of iron and increased the demand for it, and which have almost created the manufacture of steel. Stephenson, the Englishman, improved the locomotive in 1815, and in 1825 the first passenger railroad in the world was opened in England, his locomotive hauling the trains. The railroad is the greatest of all the consumers of iron and steel. Neilson, the Scotchman, invented the hot-blast in 1828; Crane, the Englishman, applied it to the manufacture of pig iron with anthracite coal in 1837; Nasmyth, the Scotchman, invented the steam hammer in 1838 and the pile driv

* *Commerce and Finance.*

in 1843; and Bessemer, the Englishman, invented in 1855 the process which bears his name and is the flower of all metallurgical achievements, a share in the honor of this invention, however, being fairly due to the co-operating genius of Robert F. Mushet, also an Englishman but born of Scotch parentage. The Siemens regenerative gas furnace, which has been so extensively used in the manufacture of iron and steel, is also an English invention, although the inventors, Sir William and Frederick Siemens, while citizens of England, were natives of Hanover in Germany.

"It is only just to add that Sir Henry Bessemer, although born in England, is the son of a French refugee who settled in England during the French Revolution of 1789, and that Benjamin Huntsman, the inventor of the process for manufacturing cast steel in crucibles, was the son of German parents, although himself born in England. Mr. Göran F. Göransson, of Sandviken, Sweden, also assisted in perfecting the Bessemer process. It was, however, enterprising and sturdy England which nursed the genius of the great inventors we have mentioned who were of continental birth or extraction, and it was in England that the ripe fruits of their inventions were first abundantly gathered." *

BRIDGES.

If Milton's information was accurate when he said,

> 'Deep to the roots of Hell the gathered breech
> They fastened, and the mole immense brought on,
> Over the foaming deep, high-arched, a bridge
> Of length prodigious, joining to the wall
> Immovable of this now fenceless world,"

we may conclude that the first bridge was a military bridge built by Satan for the purpose of maintaining the advantage he had gained, and extending from his dominions through Chaos to the Earth. But

* Swank. "Iron in all Ages."

Milton does not give the exact date of this engineering feat, neither have antiquarians been able to find the earthly abutment, so the history of bridges may be presumed to commence with some later date.

It has been held that the art of bridge building is an instinct transmitted from primitive ancestors. Certainly the suspension bridges made of thongs of rawhide and ropes of vegetable fiber which were early used in Chili and Peru were not many steps removed from the interlacing boughs of the adjacent trees of tropical forests.

OLD ROPE BRIDGE IN THE ANDES.

It is impossible to say when or where the first bridge was built, but wooden bridges were described at least as early as 1200 B. C., and Homer in his poems speaks of bridges. Until the archives of Egypt and Assyria yield their knowledge, the history of bridge building must be held to have begun with the Romans, although the wickerwork bridges of India are mentioned as far back as the history of the country goes.

Suspension bridges made of iron chains and more than 500 years old are in use in Japan to-day, although made in a time when iron was so valuable to the civilized nations that the natives of Scotland made frequent raids into England largely for the sake of the iron they were able to carry off as spoil. Iron truss bridges had been in use in Japan for 200 years when Stephenson was building his tubular bridge.

The Romans held the art of bridge making in such great rever-

ence that when the first stone arch of the Pons Sublicius was thrown across the Tiber at Rome on the site of the famous wooden bridge defended by Horatius, a special order of priests was established to foster the art, and those who belonged to the order had important privileges, while the title "Pontifex" was one of the greatest honors.

NATURAL BRIDGE, VA.

The oldest bridge in the world is the Roman bridge, Pont du Gard, at Mines, France, built by M. Agrippa in the year 19 B. C. It is 873 feet long and 160 feet high, has three tiers of arches, and is still in use.

The longest stone arch bridge ever made was built in 1380 by Visconti over the Adda river near Terezzo, Italy, the top of the arch rising 88 feet above its ends in a span of 251 feet.

The longest existing span of solid masonry is that of the Cabin John bridge near Washington, D. C. It is 220 feet long and was built in 1859 to carry an aqueduct 9 feet in diameter to furnish the water supply for the national capital. The upper surface of the water conduit is covered and forms a fine roadway. The bridge was begun in 1857 and finished in 1864 at a cost of $254,000. It is 450 feet long with a span of 220 feet, the top of the structure being about 100 feet above the bed of the stream.

Joseph Melan invented a bridge combining a steel arch with the stability of masonry. By this method a steel arch is constructed in position and imbedded in concrete, which solidifies and makes an arch of almost solid stone with a steel skeleton, thus doing away with the vibration of the steel arch while the concrete stiffens the structure and protects the steel within from the air and moisture. Such a

bridge at Steyr, Hungary, has a span of 137.76 feet, the arch rising only nine feet. The Cabin John bridge and the Niagara bridge are good illustrations of the arch bridge.

The old London bridge, once the only bridge across the Thames, was so narrow that two carts could not pass on it, so in 1671 a troublesome, progressive gentleman, name unknown, applied to the House of Commons for permission to build another bridge and precipitated one of the warmest debates that ever occurred in that body. It was urged by its opponents that the bridge would remove the condition which forced commerce to flow through London; that it would make the skirts of the city too large for the body; that it would impede navigation; that it would render the city ungovernable; that if permission were granted to build one bridge some one would soon want to build a third, and no one could tell where the pernicious practice would end. Such sound reasoning prevailed and London waited until 1750 for a second bridge.

The first iron bridge of considerable size, with the exception of the chain bridges of Japan and short suspension bridges used by miners in the North of England, was begun at Lyons in 1755 but abandoned because the material was too costly. The next to be attempted and the first to be carried to completion was built in 1777 over the Severn at Coalbrookdale, England. It was made of cast iron in the form of an arch and had a span of 100 feet 6 inches. Through some error in the plans it cracked soon after it was erected, but this corrected the error and it is still used and considered safe.

Philadelphia in 1787 wanted a bridge over the Schuylkill but there could be no pier in the river on account of the great masses of ice which had carried away such structures on other occasions. With characteristic daring Tom Paine agreed to build an iron bridge with an arch of cast iron made in segments and long enough to reach from bank to bank, 236 feet. He went to England to superintend

the casting of the bridge at the Rotherham works in Yorkshire. The pieces were cast, shipped to London, and set up for trial, and proved entirely satisfactory. The bridge occasioned considerable comment but at this juncture the French Revolution absorbed Paine, heart and soul, and the bridge was left to look out for itself and sold by the makers. However, the Schuylkill was spanned at Chestnut street by a cast iron bridge, erected in 1863. It had two spans of 180 feet each, and was the largest cast iron bridge in America, but has since been replaced by a cantilever.

The suspension bridge appeared in China, like so many other things, at a very early date, but the suspension bridge with its roadway attached to the cables and not lying directly upon the cables is an American institution, and the first one having such a construction was erected by Jacob Finlay in 1801 over Jacob's creek at Greensburg, Pennsylvania. Finlay employed as cables two chains passing over towers 70 feet apart, and hung the roadway, 12½ feet wide, to these chains.

The first wire suspension cable is believed to be that of White and Hazard, who in 1816 constructed a footbridge across the Schuylkill river above Philadelphia. Until this time chains had been used as cables in all suspension bridges, but they employed cables made of six wires, each wire ⅜ inch in diameter. The bridge had a span of 408 feet and cost only $125. A toll of one cent per passage was charged and only eight people were allowed upon the bridge at one time. The progress of 67 years is well shown by comparing the first wire cable bridge with the greatest.

The Brooklyn bridge has the longest span of any suspension bridge in the world, its central span being 1595.5 feet wide and 135 feet above the water. The work was begun January 2, 1870, and the bridge opened to the public May 23, 1883. The bridge with its approach is 6537 feet long, or more than 1⅛ miles. It was planned

and begun by John A. Roebling, but in the early part of the work an accident resulted in injuries to his foot, lockjaw (tetanus) set in, and he died. His son, Washington A. Roebling, took up the work and carried it to its completion.

The roadway of this bridge is supported by four great cables each 15¾ inches in diameter. Each cable is composed of nineteen strands and each strand is made of 278 steel wires of No. 7 gauge, so that each cable contains 5296 wires galvanized and oil coated, closely bound together. The wire in each skein is continuous and passes from one anchorage across the river to the other 139 times, at each turn passing through an eyepiece. Each turn is of exactly the same length so as to give the same tension, and it was found that if some wires were "regulated" (adjusted) at sunset and others at noon it made a difference of two feet or more between the wires at the middle of the span, so the regulating was done between daylight and sunlight to avoid the sun's influence, and forty wires a day, laid and regulated, was a good average. After the nineteen skeins were laid and regulated they were gathered together, the odd skein in the middle, the other forming two circles about it and the whole firmly bound with wire closely wound spirally the whole length of the cable.

The ends of the cable are fastened to anchorages 930 feet inland from the bottom of each tower. Each anchorage is 90 feet deep, 119 feet by 132 feet at the base, made of solid masonry and weighs 120,000,000 pounds. The anchor plates are of cast iron 16.5 feet wide, 17.5 feet long, and 2.5 feet thick, connecting with the cables by gigantic chains of 18 links abreast, each link 12 feet 5 inches long, extending in a curve upward toward the tower. For the anchor to be pulled out the entire mass of masonry would have to be overturned and the bridge would give way long before sufficient power could be brought to bear to do this.

The cables pass from the anchorage over the tops of two granite

towers 278 feet high, one on either shore. The foundations of the New York tower go down 78 feet and rest on solid rock. Near the top of each tower is an immense cast iron plate covering nearly the whole area. On this plate are a number of rollers bearing the saddles over which the cables run. Such an arrangement allows a free movement of the saddle caused by the expansion and contraction of the cable due to the changes in temperature. The original cost of the bridge was about $15,000,000 and the receipts from it for the year ending 1893, $1,590,140.03. The total cost of the Brooklyn bridge up to December 21, 1897, was about $21,000,000. The bridge of Hazard and White was the humble progenitor of the bridge over which pass, every day, more people than lived in any city on the continent at the beginning of the nineteenth century. The plans for another suspension bridge between Manhattan and Brooklyn over the East river have been approved by the War Department. This bridge is estimated to cost $15,833,000.

There are other famous suspension bridges. One built by Telford across the straits of Menai and connecting the mainland of Wales with the island of Anglesea, was at its completion, 1826, considered one of the wonders of the world. The span was 579 feet, the greatest length ever attained up to that time. The roadway was supported 100 feet above high water by four chains made of massive links of wrought iron 7 feet in length, passing from towers 194 feet high, the chains having their ends firmly anchored in solid masses of masonry back of the towers.

The gorge at Niagara, one of the greatest challenges Nature ever offered to the bridge builder, has been the scene of the romance of bridge building in which Homan Walsh, a boy expert as a kite flyer, played no small part. When the first bridge across the gorge was projected, how to get the first wire across was something of a problem. The boy and his kite were enlisted, and he entered enthu-

siastically into the scheme. As the wind blew from the Canadian side he crossed over there in midwinter and soon had his kite high in the air on the American side, but, contrary to his expectations, the wind did not die down toward evening, but increased in velocity, and so for hours the boy moved about in the cold, clinging courageously to his kite string. Signal fires were lighted on both sides and about midnight the wind began to slacken, the kite to settle, and in an hour or so the sound of cheers told him that his kite was found, but so much string had been let out that the floating ice in the river caught and broke it. The drifting ice closed the ferry and kept him a prisoner for eight days, but on arriving on the American side he found his kite in good condition and made another attempt, which was successful. The slender kite string served to draw across a cord, and this in turn a stronger until one was obtained strong enough to carry across the gorge the first wire cable and the work of construction was begun. A basket was hung to the cable and served to support the workmen and also for passenger traffic. Passengers were ferried over in it at $1 a passage, the receipts some days amounting to $125.

A suspension bridge for railroad service was soon decided upon and John A. Roebling selected as the engineer. Iron was so expensive that the cables only were of that material, the towers even being built of wood, for it would have cost a small fortune to have transported iron to Niagara, which was then "away out West." This double decked structure was completed in 1855 but in 1880 all the woodwork of the bridge was removed and replaced by steel without interrupting the traffic or meeting with a serious accident.

The demands of travel having outgrown the capacities of the bridge it was in 1896 replaced by a steel arch of 550 feet span, completed August 27, 1897, the work having been carried on without interrupting traffic, and it stands to-day the longest steel arch in the

world. The transformations which this one bridge has undergone form a series of most interesting and wonderful exhibitions of mechanical skill and daring. The Niagara river has been and is spanned by other bridges, but none have had such interesting experiences as this. March 8, 1899, the body of Homan Walsh was brought to Niagara for burial, and the train that carried it passed over the steel arch built on the site where half a century before his kite string had formed an international bridge between the United States and Canada.

THE NIAGARA STEEL ARCH.

The perfection of the suspension bridge is largely due to John A. Roebling, who remedied its lack of rigidity and the swaying produced by wind by introducing a system of stays and stiffening trusses. He built the first suspension bridge across Niagara in the face of almost unanimous predictions of failure by British engineers, for all the suspension bridges erected in Great Britain had up to that time been deficient in rigidity. One or more of them had been blown down, and Stephenson's tubular girder was most popular there for long spans.

The girder type of bridge is the strongest form for long spans yet devised. The simplest illustration of this type is a tree trunk lying

across a water course. The principle has been elaborated in bridge building and architecture until the tree trunk has been changed into large beams (chords) connected by braces and tension rods forming a truss that may look almost like lattice work. The ends of the girder rest upon foundations at the river bank prepared for it. In common practice these are called "abutments" as distinguished from detached portions of masonry erected between the abutments called "piers." Suppose a space of a few feet to be bridged and a plank 12 inches wide and three inches thick thrown across it. If the plank were not strong enough and another placed beside it, the two, if the weight were equally distributed, would bear twice the load of the first. If one plank be placed on top of the other and the two spiked firmly together they will bear not twice but four times the original load. If the under plank be set up on edge and the upper plank spiked to it making a letter "T," it will support seven times the original load. If the planks be sawed in two, giving four boards 1.5 inches thick and a foot wide, and these be nailed together in the form of a long box it will support nineteen times the original load. Robert Stephenson, so prominently identified with the early history of the locomotive, applied this principle to bridge building.

The Tubular Bridge. A suspension bridge at Conway failed and Stephenson applied to Parliament in 1846 for permission to build a bridge of a new design of which he was the inventor. The permission was secured and in 1847 the Conway Tube bridge was begun. It was made of boiler iron plates four to eight feet long, about two feet wide, and five eighths inch thick, put together and riveted by hand, forming a tube 412 feet long, 14 feet wide, and 25 feet high in the middle. It weighed 1300 tons, gave satisfaction, and is still in use. The Victoria bridge at Montreal was Stephenson's masterpiece. This is a quadrangular tubular bridge 16 feet by 22 feet in cross section and 1¼ miles long. It was completed in 1859 and cost about $7,000,000.

The tubular bridge served its purpose but it is now known that a different arrangement of the metal will give greater strength for the same weight. The amount of material and workmanship required render them the most costly of all structures, and both the Britannia and the Victoria bridge ruined the companies that built them.

THE BRITANNIA TUBULAR BRIDGE ACROSS THE MENAI STRAITS.

The first steel bridge in the world was that built by Captain James B. Eads across the Mississippi at St. Louis. Although the inventions of Bessemer, Mushet, Kelly, and others had made steel available in place of wrought iron since 1858, it was not until 1874 that the St. Louis bridge was completed. This structure gave birth to a new industry, the manufacture of structural steel, and the condition of the art at that time was such that more steel was rejected than was used. Special machines were invented and built to test the materials, and the accurate knowledge now possessed of the physical properties of steel is more the result of the building of this bridge than of any other one structure. Each span is composed of four arches formed of steel tubes nine inches in diameter. Each tube is straight but wedge-shaped pieces at the joint give form to the arch. The arches are held together as well as apart by a system of diagonal steel braces and tension rods. There are three spans in the bridge: the center 515 feet, and the end spans 497 feet each.

The longest bridge in the world was the lattice girder bridge built over the Tay in Scotland. It was 10,396 feet in length, lacking only fifty-five yards of two miles. It was completed in 1877 at a cost of £350,000, but went down the night of December 28, 1879,

carrying with it a passenger train and seventy-five passengers. A board of inquiry reported that the failure was caused by faulty construction and that there were no understood rules or requirements existing in Great Britain regarding the computations of wind pressure, although in France an allowance of fifty-five pounds per square foot, and in the United States fifty pounds per square foot, was generally required. It was replaced in 1887 by the Tay viaduct, 10,780 feet long, which holds the record as the longest bridge in the world. It is of the same type as the original but much stronger.

The cantilever bridge holds the record for the greatest distance spanned. The cantilever, a beam, a truss, or a girder, balanced at some point near the middle, is extensively employed in bridge building as well as in architecture and hoisting machinery. If a stick be broken across the knee the fibers of the wood farthest from the knee are put in tension while those nearest are forced together or put into a state of compression. When the ends of girders are placed on abutments the weight puts the tops of the girders in compression and the lower parts in constant tension. Paradoxical as it may seem, the strength of a girder is just about doubled by an arrangement that turns it upside down and cuts it in two at the middle, for the cantilever is made by balancing a girder by its center on a pier instead of raising its ends on the piers, and puts the top in tension and the bottom in compression. The center of the truss is made higher than the ends, which to some extent hang from the center. The roadbed, instead of running over the top or on the bottom of the truss as it does in the girder type, runs right through the center of the cantilever.

The Forth bridge, a cantilever type, has two spans of 1710 feet, each exceeding in length by more than 100 feet the greatest span of the largest suspension bridge in the world. The Eiffel Tower represents the greatest height achieved by man's daring, yet with its boasted height of nearly 1000 feet it could be laid length-

wise on one of the spans of the Forth bridge and lack 700 feet of reaching from pier to pier. The bridge stands on three piers which support the 53,000 tons of steel of which it is built. Each of the great cantilevers rises 340 feet above the piers, or 361 feet above water level. The base of the foundation is 91 feet below the water level, and the distance from the base of the foundation to the top of the cantilevers is greater than that of the highest building in the world. Wind pressure that wrecked the Tay bridge has here an allowance of 56 pounds per square foot made for it, and with the greatest rolling load to which the bridge will ever be subjected and a hurricane blowing, the bridge would be able to sustain a load four times as great. The bridge was opened March 4, 1890, and cost £4,000,000 or nearly $20,000,000. This great structure, which may be justly considered the most gigantic piece of mechanism in the world, stands as a monument to its builders, William Arrol and Company of Glasgow.

THE FORTH BRIDGE.

Enormous as are the cantilevers of the Forth river bridge it is evident that the system has not reached its limit, for experiments conducted by the United States government determined that it was practicable to reach a span of 4335 feet, or more than four fifths of a mile.

The Kinzua viaduct, on the Bradford branch of the New York, Lake Erie, and Western railroad, furnishes a sample of the expense of keeping pace with the demands of progress. The viaduct is 301 feet above Kinzua creek, has a length of 2052 feet, and is supported by 20 steel towers resting on foundations of masonry. The bridge cost but $275,000 and was completed in 8½ months from the

time work was commenced on the foundation, all the steel being put in place between May 5 and August 20, and during the whole operation no more than 125 men were employed at one time. It was built to sustain the heaviest engines and cars laden with the lumber and soft coal of Western Pennsylvania. The engines then in use weighed 103,400 pounds, the boilers carried a steam pressure of 125 pounds per square inch, and the cars had an average capacity of about 40,000 pounds. After eighteen years of service the bridge was rebuilt, although in excellent condition, giving place to a far stronger one because the demands of traffic had called into action locomotives weighing 190,000 pounds with boilers carrying a steam pressure of 200 pounds per square inch and cars having a hauling capacity of 100,000 pounds. In other words, the car capacity had increased from 100 per cent. to 150 per cent. and the weight of the engine more than 80 per cent.

The Pecos viaduct of the Southern Pacific railroad, one of the highest in the world, is 2180 feet long, has 48 spans, and was built by 67 men in 87 days. The rails are 328 feet above the water and the viaduct is the highest one on the North American continent. Bolivia has at Loa a viaduct 800 feet long and 336 feet high. This is the highest in South America. At Garabit, France, there is one 1852 feet long and 406 feet high; the highest in the world. Germany has one of the highest bridges in the world. The Mungsted bridge over the Wupper river furnishes a passage for the Solingen-Remscheid

THE GARABIT VIADUCT.

railroad. It is 1640 feet long and the top of the rails are 354 feet from the water underneath. It is a steel bridge of the arch type, the top of the arch rising 225 feet above its base. It has a span of 557.6 feet, second only to that of Niagara.

Another famous viaduct is that over the Gokteik gorge in Burmah to furnish a direct railroad line from Rangoon to China. Almost insurmountable obstacles were connected with the work, for the bridge is 150 miles from any seaport and everything had to be transported overland. The viaduct is about 2300 feet in length and in some places more than 320 feet high. The contract was awarded to the Pennsylvania Steel Company of Steelton, because time was an important factor and the Steelton Company would agree to complete the work in half the time asked by their closest competitor. When the difficulties surrounding the work are taken into consideration it may be considered as one of the great feats of modern engineering.

A Bridge for the Soudan. Late in 1898 the British government decided to build, for the benefit of Kitchener's expedition in the Soudan, a bridge across the Atbara river, a large tributary of the Nile. The designs were drawn in London and submitted to American and British bidders, but when reviewed by the engineers on the spot the plans were shown to be impracticable and telegrams were sent the bidders asking how quickly they could make delivery of a bridge according to new specifications. Owing to labor troubles, the British firms could not guarantee delivery under six months and the contract went to an American firm that agreed to put the bridge on board the vessel in New York harbor in six weeks. The contract was signed January 30, 1900, and in thirty-seven days the complete bridge was turned out, five days ahead of contract time. The following is an extract from General Kitchener's speech at the ceremony of opening the bridge:—

"In November and December every effort was made to place the order for the superstructure in England, but it was found impossible for British firms to supply so big an undertaking in the time allowed. This matter is one of considerable regret to me personally. I think it demonstrates that the relations between labor and capital in our country are not such as to give sufficient confidence to capitalists to induce them to run the risk of establishing great up-to-date workshops with the plant necessary to enable Great Britain to maintain her proud position as the first constructing nation in the world. Well, gentlemen, where Englishmen have failed I am delighted to find our cousins across the Atlantic have stepped in. The opening of this bridge to-day is due to their energy and ability and the power they possess in so marked a degree of turning out works of this magnitude in less time than can be done by anyone else. I congratulate the American foremen and workmen on the excellent success which has crowned their efforts in the erection of this bridge in the heart of Africa, far from their homes, during the hottest months of the year, and depending solely upon the labor of men speaking a foreign tongue. They have shown by their work the real grit they are made of."

The New Bridge at Quebec. Quebec is to have a bridge of the cantilever type crossing the St. Lawrence river. It will have a central span of 1800 feet, which when completed will be the widest span in the world, exceeding that of the Forth bridge by about 100 feet and of the Brooklyn bridge by about 200 feet. The contract for the bridge has been let to the Phœnix Iron and Steel Company of Phœnixville, Pennsylvania, and the structure is to cost $4,500,000.

Bridge building has been reduced almost to an exact science, the last decade having seen great gains in this direction. The greatest disasters, those of the Tay bridge and at Ashtabula, have been shown by investigating committees to be due to faulty con-

struction that to-day would be recognized and at once corrected, and bridges are now planned to carry from four to ten times the load likely to be required of them.

A steel bridge made of good material, with the demands upon it within a reasonable margin of safety, will last for centuries if the steel is protected by coats of paint from corrosion. The popular belief that a crystallization insidiously saps the strength of steel has no foundation in fact, and is a fiction pure and simple. Steel protected from corrosion can lose its life only by being strained beyond its elastic limit, and if the bridge is designed so that none of the parts are strained beyond this limit such a bridge will outlast most nations.

Some of the Longest Bridges in the World. The following is a list, although incomplete, of some of the longest bridges in the world. In general the lengths given include the approaches as well as the main spans.

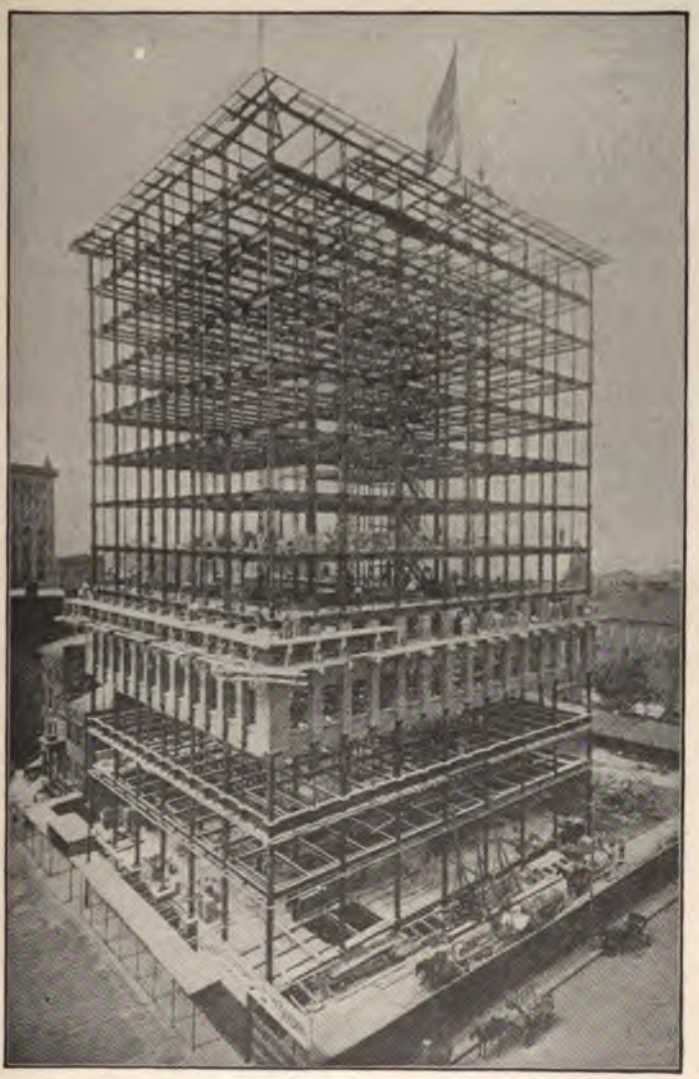
New Tay Viaduct, Scotland	10780	feet
Ohio River Bridge, Cairo, Illinois	10560	"
Forth Bridge, Scotland	8295	"
Missouri River Bridge, Kansas City, Mo.	7633	"
Hudson River Bridge, Poughkeepsie, N. Y.	6770	"
Victoria Bridge, Montreal, Canada	6520	"
New Susquehanna Bridge, Havre de Grace, Md.	6315	"
East River Bridge, Brooklyn	5989	"
Cincinnati and Newport Bridge, Ohio River	5925	"
Wooden Bridge at Columbia, Pa.	5366	"
Cincinnati and Covington Bridge	5360	"
Rapperswyl Bridge at Lake Zurich	5333	"
Ohio River Bridge, Louisville, Ky.	5280	"
Volga Bridge, over the Sysrau, Russia	4947	"
Moerdyck Bridge, in Holland	4927	"
Dneiper Bridge, Jekaterinoslaw, Russia	4213	"
Kiew Bridge, over the Dneiper	3607	"
Barrage Bridge, Delta of the Nile	3353	"
Kronprinz Rudolph Bridge, Vienna	3266	"
Dneiper Bridge, near Krementchoug, Russia	3250	"
Bommel Bridge, over the Meuse, Holland	3060	"

Sky Scrapers.

The closing decade of the nineteenth century witnessed a startling revolution in architecture. Fifteen years ago the modern steel skeleton building existed only in the constructive imagination of the most progressive architect. Ten years ago it was just coming into use. To-day it is so common as to attract no attention.

The Park Row Building.

Tall buildings are almost as old as architecture itself, but the tall building that can be put to practical use is a modern invention. The base of the great pyramid covers more than 13 acres of ground and its height reaches 451 feet. Ancient Rome had tenement buildings 12 stories high at the street front, 15 or more at the rear, and these became so dangerous that Augustus limited their height by law to 60 feet on the street front. The ruins of Pompeii show that the height of some upper stories was about 4 feet, 3 inches. Picture the result of overcrowding in such rooms in an age that knew nothing of sanitary engineering! Nero's fire effectually wiped out the most wretched of these buildings and he remodeled the plan of the city, made wide streets in place of narrow alleys, and issued an edict



High Building, Steel Skeleton in Process of Construction.

that no house should be more than twice as high as the width of the street on which it stood.

St. Peter's at Rome is a monument not only to the Apostle but to the architectural skill and daring of thirteen centuries. It is so enormous that figures fail to convey any adequate idea of its true size. The distance from the doors to the apse is a little more than ⅛ mile. It is 1½ mile from the pavement to the lantern in the cupola, and the top of the cross is 476 feet above the pavement. Eighty thousand people can be seated within this vast cathedral, where 50,000 seem but a slim attendance. On the square, ellipse, and steps in front of the cathedral an army of 200,000 men could be drawn up in military order. Those employed in its decoration or construction comprise some of the greatest names in painting, sculpture, or architecture, and they have produced the most magnificent church building in the world.

The highest building in the world composed of masonry is the Washington monument, a plain shaft 500 feet high, 55 feet square at the base, 30 feet square at the top, surmounted by a pyramidion 55 feet high, giving a total height to the monument of 555 feet from the ground. But its walls are so immense and cumbersome that they would never do in a building intended for practical purposes. Such buildings are monuments upon which the world's great architects and sculptors have written the records of their achievements, but this utilitarian age has little use for monuments in business and the modern steel sky scraper that has risen in response to the demand for a more concentrated office life is quite a different structure.

The tendency of mankind seems to be to gather within as small working limits as possible. Even in the walled cities of the Middle Ages space became so valuable that nearly all the houses were built to the extreme height allowed by law, or until limited by the strength of the materials then employed. Our complex civilization

offers no exception to this tendency, in spite of all the arguments and dangers attendant upon the concentration of a population. The conditions exist and must be met.

The Reason for High Buildings. Time was when nearly all business was transacted in scattered offices located in widely separated stores, factories, or warehouses. The stores, factories, and warehouses have grown larger, offices have been divorced from them and grouped together in enormous buildings erected for that especial purpose within large cities. The office is located where it can be in closest touch with the greatest number of prospective buyers. The factory or warehouse is located where the shipping facilities are best and the running expenses lightest. It is usually many miles from the office, often in another state or province, not unfrequently in another country. By grouping the offices of numerous different enterprises within a large city, time is saved, business can be transacted much more satisfactorily, working hours shortened, opportunity given for leisure and self improvement, vacations made possible,—all to the benefit of the office using part of our population. The business man at his desk in Ottawa can, without leaving his office chair, talk with a customer in Washington. The man in New York can communicate with London in the morning and get a reply before going to luncheon.

Better service can be given and the sanitary conditions made better at less cost in a large building because of using larger, hence more economical power, heating, lighting, and ventilating plants than can be profitably maintained in smaller buildings.

One argument much used against tall buildings containing enough population to make an average sized country town is that they cause a great congestion in street traffic. Suppose two arrangements of offices, one in which 500 offices are contained in five buildings, the other having them all in one building. The represen-

tatives of these offices all doing more or less business with each other must meet, and to get from office to office, use the street to get from building to building. In the modern arrangement the representatives of one office need not leave the building to visit every one of the other 499 offices. Inasmuch as the representatives of various allied industries tend to group themselves together in one building or district, this is not a theoretical but a practical proposition, and it needs no argument to prove that the big office building tends to relieve rather than increase street congestion. The concentration of office population shortens the distance from office to home and therefore shortens the average haul per passenger on street railway lines. If this population were scattered over a large area, as in the old style of office buildings, much valuable time would be lost in this daily trip. The tall office building also increases the profit in operating street railways, because, while they serve the same number of people, less power is required on account of the less average distance traveled by each person.

Enormous Prices for Land. In the business and office districts of our large cities ground is so valuable that, to get a fair income on the investment, every inch of renting space possible must be utilized. The boundaries of the building lot being fixed, the only way to increase the renting space is to make the building taller. The ground on which the Manhattan Life Building in New York stands was purchased for $157.02 per square foot; and that under the American Surety Building cost from $176 to $282 per square foot. Every inch of land between King William's statue and Trinity square in London cost over $150 per inch, or at the rate of $950,000,000 per acre. Small wonder that the "sky scraper" shot up as soon as the inventors had made steel strong enough to hold the structure together and cheap enough to render its purchase possible. In the year 1880, land in Cannon street, London, sold for $30 a square foot, but in

1886 the same land could not be bought for $75 a square foot. The rental of the corporation property in Liverpool in 1672 was only $62, while to-day it furnishes a revenue of $62,500,000. In the same city land was recently purchased at $1130 per square yard for an addition to the Stock Exchange. Such enormous land values rendered obsolete the building of four or five stories. They stimulated the inventive faculty of the best engineers to devise a plan that would give, in proportion to the ground area, the greatest floor space consistent with the requirements of strength, ventilation, lighting, heating, and protection from fire. Nothing less could enable such an investment to pay a dividend.

Overcoming Difficulties. But many substantial, practical difficulties interposed themselves between the desirability and the feasibility of tall buildings. Tenants do not like to climb long flights of stairs. Their reluctance to do this called out that high speed vertical railroad, the passenger elevator. This was not the only difficulty to be overcome, for if a building were made higher its walls must be made thicker and stronger, to carry the added weight. Soft brick will crush under a pressure of about 300 pounds per square inch; ordinary brick under a pressure of 2500 pounds; the best pressed brick, 7000 pounds; and granite, 20,000 pounds. The builder has also to reckon with the disintegrating effects of frost, heat, and moisture, and it is not safe to subject such materials in a building to more than one tenth the strain they will resist in a testing machine. The resisting power of the material practically limited the high building to six, eight, or ten stories, for the lower walls must be thick, almost solid, occupying much valuable renting space, rendering large windows impossible and consuming enormous quantities of building material. For a time it seemed as though a city had reached the limit of its growth in thickness and must expand in its other dimensions, length and breadth. Masonry gave splendid op-

portunity to make beautiful buildings, but architectural beauty is rather a secondary object with the building speculator, when the purchase price of his land would cover every square foot of it with gold coin. He wants to make his building beautiful enough to attract tenants, but his artistic aspirations are not wont to soar beyond the point where the beauty of his structure will not add to the revenue received from it.

Throughout all the history of invention it is noticeable that great improvements come only in response to urgent need. The steel skeleton method of building solved the building problem, and the improvements which greatly reduced the cost of steel made this method practicable. As an example of the rapidity of this reduction in price, steel beams delivered in Chicago in 1892 cost $64 per ton; in 1894 the price under the same conditions was $30 per ton. Steel furnished a building material which was both cheap and efficient and by the use of which many of the old difficulties could be overcome.

Previous to 1885 cast iron had been used to a limited extent in building, but it is at best a very unsatisfactory material except for pedestal blocks and work of that class. Steel, costing only a trifle more, will give the same strength with a much less weight and much greater security, for it is not so liable to flaws and defects as cast iron.

Wrought iron was used in some of the early skeleton frames, but its inferiority in strength, weight, and stiffness to steel, and the cheapening of steel, soon drove it out of use. The first American building in which steel beams were exclusively used was the Science Hall of the University of Wisconsin. In 1888 the first steel lintels in a high building were used in the Tacoma Building in Chicago. In the same city in 1889 steel columns were first used in the erection of the Rand-McNally Building. Metal skeletons had not yet been entirely depended upon and were largely experimental. But the result

of the experiments were so satisfactory that in 1890 architecture underwent a revolution and we can justly say that from that year dates the era of steel buildings.

In a steel skeleton building "the old order changes, yielding place to new," for instead of the walls supporting the framework of the building the framework supports the walls, and the latter need be no thicker than are necessary for protection and fireproofing. The walls of each story are supported not by the walls underneath but by huge steel beams which are a part of the skeleton. The walls are connected not at the bottom but at any point where it is most convenient and construction may begin simultaneously at three or four different levels. Wall building in mid-air has an uncanny appearance to the uninitiated.

St. Peter's required 1300 years for its completion, dating from its first basilica, but our modern sky scrapers are often projected, begun, and completed in a single year. In the sky scraper the basement, cellar, or sub-cellar usually contains the machinery necessary for the running of the building; the ground floor is occupied by stores or large banking establishments, the second story by large offices, those from the third story upward are made nearly alike, form the main bulk of the building, and are the smallest offices, which determine the "unit" of construction. Above all comes the attic, an important part, for it contains many things essential to the welfare of the house.

Calculating for a "Sky Scraper." The unit, usually determined by the size of one or the combined size of two or three small offices, decides the floor plans, and in planning the building two points must be ever kept in mind; first, strength; second, utility. Columns necessary to the stability of the building are so disposed that they will coincide with the walls and partitions as far as possible, although in very large rooms their exposure cannot be

avoided without jeopardizing the strength of the building, which must be maintained at all times. The architect plans the building from below upward, and then beginning at the top works down to verify his figures and calculate the exact weight of the building, or "dead weight," which includes the steel work, the wall, partitions, floors, woodwork, plumbing, machinery, and every *permanent fixture* in the building. Each floor is calculated separately for no two floors exactly agree. To the total dead weight a liberal amount is added as a factor of safety. The "live weight," also added to the dead weight, covers all movable articles, as furniture, books, safe, stock, apparatus, used by the occupants of the building and the weight of the occupants themselves. The building laws of New York city fix this at 100 pounds per square foot of floor space. This is far above any live weight actually attained in practice, the heaviest loads in Boston showing only 40.2 pounds per square foot, while the average was slightly over 33 pounds.

The site of the proposed building is next examined, deep holes bored if necessary to determine the material underlying. Bed rock is the most satisfactory base, but it sometimes lies so deep that it is not practicable to go down to it. Sand and gravel properly treated make an excellent base and are often built upon. Many Chicago buildings rest upon hard clay. The character of the ground being determined, the foundation is planned to suit the existing conditions.

The problem of the foundation being out of the way, attention is turned to plans for heating, lighting, power, plumbing, ventilation, and, last but not least, the decoration of the building in such a manner as not to conflict with its utility, and all these details are worked out before a single spadeful of earth is turned. The work of the architect being finished that of the engineer begins.

Foundations. In a large city "excavation" means more than merely making a hole in the ground, for the buildings erected in

years past are light when measured by modern standards, so their foundations have been "floated" and rest on more or less soft earth at the depth of only a few feet below the surface. When excavations for the foundations of a sky scraper are made next one of these old buildings, the earth swells out or "flows" at the side and unless prevented the old foundation shifts and the building topples over.

The pneumatic caisson is one of the most satisfactory methods of overcoming this difficulty. The caisson is a huge steel tank turned bottom upward, and of such size that the area of its roof is equal to that of the pier to be supported. All joints are made practically air-tight, the sides and the roof are strongly braced and in the roof are cut two holes, the larger about 3 feet in diameter, in which is fitted an upright steel tube of varying length. Within the tube is an air lock, *i. e.*, a chamber with two sets of doors opening downward. Men from the outside enter the air lock by the upper door, close it, the air is turned on until the pressure in the chamber is equal to that of the caisson underneath, when the lower door is opened and the men descend. In arising the process is reversed, a lock full of compressed air being lost at each operation. The air lock also affords an opportunity for the men to become accustomed to the change of pressure, for it is highly dangerous for them to pass directly from the high pressure within the caisson to the atmospheric pressure without, and workmen are liable to attacks of caisson disease, which often produces paralysis and even death. Through the small hole in the roof, usually 4 inches in diameter, a vertical pipe is passed terminating in a right-angled elbow about on a level with the lower edge of the walls of the caisson.

The caisson is usually brought to the building site ready-made, placed exactly over the spot it is intended to cover, and of its own weight sinks a short distance. Workmen enter it and dig away the earth underneath and hoist it out through the top; the caisson sinks

until its roof is on a level with the ground. Then the bricklayers begin and build on top of the caisson a pier of the same size. The heavier the pier becomes the deeper the caisson sinks, the men inside continually digging away underneath it that it may settle. The bricklaying is all done on the ground level and there is no expense incurred in hoisting or lowering this material. As soon as the same depth as that of the adjoining foundations is reached the air lock is closed and the work then begins under compressed air, which prevents the shifting of the adjacent ground and the entrance of water. When it becomes difficult to keep up an even pressure in the caisson and remove the excavated material by way of the air lock the material is pulverized and thrown in front of the mouth of the small pipe, a valve in the pipe is opened, and the material literally blown out. The operation of digging out below and building on above is continued until the desired depth is reached. When bed rock is struck, if the rock is level nothing is done to it, but it usually slopes, and if the slopes be gentle its face is roughened to prevent the material resting upon it from sliding. If the slope is considerable the rock is either cut to a level or into steps. The large tube and the small pipe are continued upward as fast as the pier is built, and when the caisson rests upon bed rock and the brickwork of the pier is finished, the interior of the caisson and the pipe is filled with concrete and the pier completed without disturbing in the least any of the surrounding structures. The sinking of one caisson does not interfere with the sinking of another one close by and one large air compressor can be profitably employed to supply several caissons, thus saving expense and time.

A foundation built on piles is frequently employed where the bed rock is at a great depth and the weight to be supported not excessive. Piles are long straight timbers from 8 to 18 inches in diameter and from 20 to 40 feet long. They support the weight

resting upon them either by being driven through soft, yielding material to hard strata underneath, in which case they sustain a vertical pressure, or by the friction which their sides offer to the material in which they are driven.

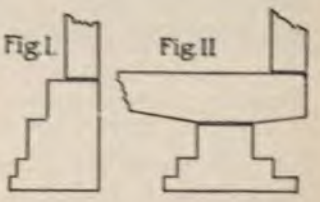
Sand piles are sometimes used in soft earth free from water. These are made by sinking holes six or eight inches in diameter several feet and filling them with sand, the sand being free to move. The weight of the foundation resting upon it is distributed to the sides as well as the bottom and if the soil underneath be kept from spreading sidewise the foundation is a fairly good one.

Wooden piles driven under water will practically last forever. Excavations in the Thames have brought to the surface in good condition wooden foundations placed there in the fifteenth century and a Viking ship of the tenth or eleventh century was excavated in Norway in 1875 with its timber perfectly sound.

Steel grillage is often used in soft soil, as in that of Chicago. The area of the foundation must be great enough so each square foot will not be called upon to carry more than 1½ or 2 tons. After the excavation has been made a thick layer of concrete is put in. On this is placed a tier of parallel steel rails which have been heated and dipped in hot asphalt or coal tar to protect them from rusting. The spaces between the rails are tamped full of concrete, a second tier of rails are laid on at right angles and the process repeated until the desired depth has been obtained.

In big buildings it is essential that every inch of area be utilized and the walls are therefore set exactly even with the boundary line. But it would never do to rest all the weight of a modern sky scraper on the outer edge of a foundation, for the latter would tip over under its load. The cantilever (Figures I. and II.), so extensively used in bridges, is here employed except that it is turned upside down. The pier is built with its center some distance inside the

party line, and the wall does not rise on the pier but on the short arm of the cantilever, for which the pier acts as a fulcrum. The long arm of the cantilever is carried back under the building and there helps support central columns or is anchored to a central pier. It can be truthfully said that the walls of a modern building do not even rest upon the foundation.



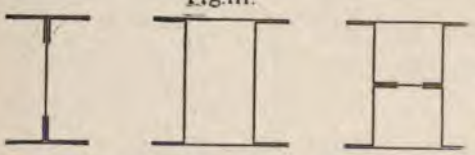
Many buildings extend several stories below ground and these stories are usually filled with the machinery necessary for running the building, but many of the spaces are coming to be used as barber shops, restaurants, and offices. Such possess the advantage of an equable temperature and freedom from noise and dust. It would not be surprising if the next revolution in architecture consisted in digging deeper into the earth instead of building higher into the air. White glazed tilings for walls, electricity for light, steam for heat, forced draft for ventilation, and an efficient elevator service render it entirely possible.

The steel used in the skeleton of a sky scraper must be of good quality and the building regulations of cities usually make provision for its test, and the specifications of any important building are sure to provide for it. In a general way the framework may be said to be divided into two parts, the vertical and the horizontal. The vertical part consists of columns; the horizontal, of beams, girders, and lintels. The steel work is not made solid, for that would be too heavy and expensive, and greater strength in proportion to the weight can be obtained by building up the columns from several pieces.

Cross sections of three forms of column construction are represented by Figure III. The beams are usually rolled solid and the form most commonly employed is the I beam, so called because its

cross section is the shape of the capital letter "I." This form gives the maximum strength with the minimum material. Columns are made as long as the height of two stories and so arranged that they will break joints at alternate floors, thus giving a much stiffer structure than if the joints were all on the same level. The foundation piers are usually capped by a thick granite pier stone upon which is placed a huge cast iron pedestal to receive and distribute the pressure equally over the entire area of the pier. On the pedestal is set the column base made of steel and strong enough to support all the weight above. All iron and steel work is carefully protected from moisture, usually by giving it a coat of hot asphalt, and the steel work receives at least two coats of protective paint.

Fig. III.



Usually the framework of each floor is practically completed before that of the next is set up. The parts are hoisted to their places by aid of derricks and bolted together until they can be riveted. It speaks wonders for the accuracy of modern workshops that the steel skeleton of a building can be planned in one city, manufactured in another, shipped to and set up in a third, and the whole found to accurately agree. As soon as the beams are in place the gang of riveters take up their work. Numerous portable forges are located at convenient places, the rivet is heated, tossed to the riveter, who presses the trigger of a pneumatic hammer, and the rivet is headed in an instant.

Wind pressure must be allowed for if the building is to exceed 75 feet in height. An allowance of 30 pounds is usually made for each square foot exposed, a pressure sufficient to blow an empty freight car off the track.

The rapidity with which the steel skeleton can be erected is as-

tonishing. The Fisher Building of Chicago has a frontage of 100 feet on two streets and 70 feet 6 inches on a third. The first piece of structural steel was set in this, October 3, 1895, and nineteen stories, including the attic, were put in position in 26 days, 5 days being lost on account of bad weather.

As soon as the framework of a floor is set and riveted the work of building the walls and the floor is begun at once, and by the time the roof is on nearly all the walls and floors are completed and the finishers are at work in the lower stories. In some buildings the lower floors have been finished and used before the roof was completed. The capital invested, from which no return can be obtained till the building is rented, renders the economy of time essential and the work is so thoroughly systematized and skillfully planned that but little time is lost.

Fireproof buildings do not exist if we are to understand by fireproof a building that cannot be injured by fire. Steel skeletons under the influence of heat expand, lose their rigidity, and collapse under their load. Special precautions are taken to construct the building so that different divisions can be isolated. Fire resisting floors are used, metal doors employed at frequent intervals along the passages, the openings from one story to another made as few as possible, apparatus within the building for fighting fire,—all tending to reduce danger. Tiling for floors of offices and corridors and aluminum or some other metal for finishings, in place of wood, reduce fire risks.

The steel skeleton is protected by a layer (walls) of some incombustible material, usually fire brick or terra cotta. Granite and marble are not good fire resisting materials; under the influence of heat marble crumbles into dust. Fire brick can withstand intense heat, as witnessed by their use in iron and steel smelting. Terra cotta, which is almost as good, is made by mixing fire clay with saw-

dust and molding the mass when plastic into any desired form, for intricate figures are easily molded from it and it has come to be largely used in place of stone carvings in decorated buildings. When molded, the terra cotta is subjected to an intense heat, which bakes the clay and burns out the sawdust, leaving a light, strong, porous, fire resisting material of the shape and size desired. The fire brick, of which protective walls are made, are pressed in such shape that they bond or interlock in the wall and are set in cement mortar which hardens and becomes almost as strong as the brick itself. An air space is left between the brick and the steel, for air is one of the best nonconductors of heat. Fire brick are expensive and for a large building may easily cost $50,000.

Fireproof floors have been the subject of numerous patents. The general principle is about as follows. The parallel steel floor girders are connected at right angles by lighter floor beams dividing the floor space into regular rectangular spaces. These spaces must be covered by the floor and over them bars are hung from beam to beam, or arches are built of hollow fire brick to form a base on which a layer of concrete coming 2 inches above the floor girders is spread, and on the concrete are set wooden stringers to which the rough flooring is nailed. On the lower edge of the beams a heavy horizontal wire netting is hung to which is attached the metal lath which in turn supports the plaster of the ceiling. The modern roof amounts practically to another floor.

Windows of Steel and Glass. All skylights and most exposed windows are of glass, made with a network of steel wire pressed inside it, so if the glass is broken the pieces do not fall out but stay in place. The wire increases the strength of the glass and reduces the danger of fire from exposed windows, but most windows are further protected by rolling steel shutters or ironclad doors.

Spaces in the walls are left for steam pipes, gas pipes, electric wire

conduits, plumbing, and water pipes, as well as for the ventilating system,— all hidden away in the walls so that they may not take up valuable floor space. The Manhattan Life Building has 10½ miles of piping and 35 miles of electric wires. Electricity is generally employed for lighting and most large buildings have their power and lighting plants. Steam heating is most satisfactory, and modern buildings are now furnished with cooling systems so that not only is the cold of winter kept out, but the heat of summer is made bearable.

The elevator or vertical railroad is the heart of the sky scraper and through this channel flows several times each day the circulating life of the building. Upon the efficiency of this system depends the success of the building, for tenants do not like to climb stairs. Two general systems of elevators are used, the hydraulic and the electric. Very tall buildings have "way" and "express" elevators. One set of elevators stops at each one of the first ten floors, another set makes the first stop at the eleventh and stops at every floor up to the twentieth; the third will not stop until the twenty-first floor is reached and will serve the floors above that level. Freight elevators are also required, moving much slower but with a great lifting capacity.

The air cushion, one of the best safeguards against accidents in the elevator service, has the bottom of the elevator shaft made air-tight, into which the elevator fits closely, so if the cab falls it is brought to a gradual stop by the cushion effect of the air in the bottom of the shaft. Numerous safety devices have been invented intended to grasp the guides at the sides of the shaft and stop the cab, but serious accidents which occur from time to time show that the system is not yet perfect. In "The Rookery," a modern office building of Chicago, one of the first built and by no means the largest, there are ten passenger elevators for the 3200 people in the building. An account kept from day to day shows that from 22,000 to 23,000 passengers are carried,—enough to make quite a respectable

small city. "'The Rookery' is a town within itself. It has in the basement its own power plant, its own pumps, its own heating arrangements, its own electrical service. It has its own carpenters, its own painters, its own plumbers, and every mechanic necessary is employed in the building permanently. They start from the roof and work down to the ground as regularly as the years roll on. By the time they reach the ground itself, or the basement, the top of the building is in a condition to need their work once more, and they repeat the process, so that the building, after its twelve or thirteen years of life, is practically as good as it was on the day it was built."

The Masonic Temple of Chicago has 20 stories, 14 elevators, and rises 274 feet above the sidewalk. It was built in 1891 and cost 58 cents per cubic foot. The Ames Building of Boston, the highest in New England, has 13 stories and is 186 feet from the curbing to the top of the cornice. Broad Street station of the Pennsylvania railroad is the tallest business building in Philadelphia, being 10 stories high in the tallest part and rising at one corner to a height 240 feet above the curbing.

The Pulitzer Building, the home of the New York *World*, when built in 1890 was the tallest business building in the world. It is 15 stories high, cost $1,500,000 and measures 375 feet from the bottom of its foundations to the top of the flagstaff. The following table gives the number of stories and the height of some other famous New York buildings:—

	Stories	Height
Ivins Syndicate Building	29	309 feet to roof top 386 " " tower top
Manhattan Life Building	17	246 " " roof top 348 " " tower top
St. Paul Building	26	308 "
Amerian Surety Building	23	306 "
American Tract Society Building	21	306 "
Empire Building	20	304 "
Commercial Cable Building	21	304 "
Bowling Green Building	19	272 " 6 inches
New York Life Building	12	270 " to tower top
Central Bank Building	15	219 "
Waldorf-Astoria Hotel	16	214 "

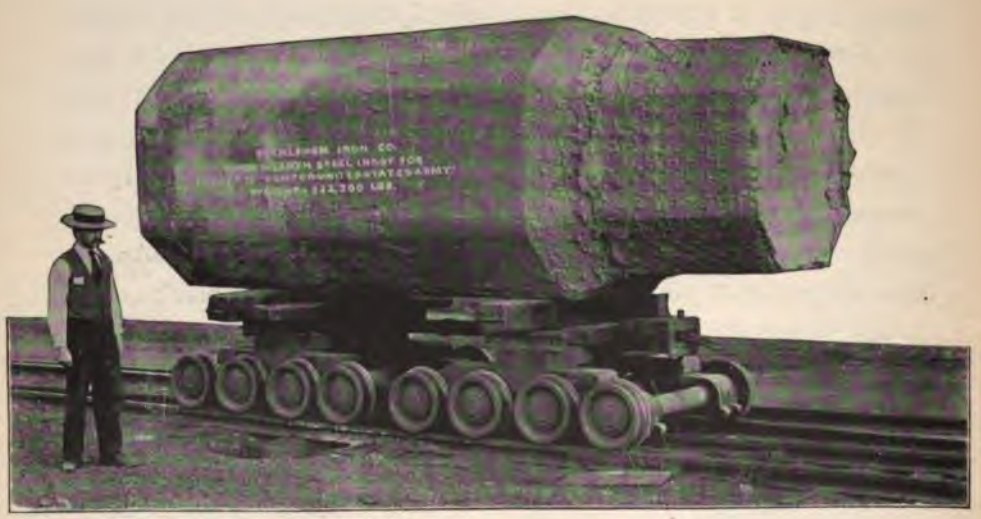
The Boston South Terminal station occupies 35 acres of ground, of which 13 acres is covered by the building itself. It seems but appropriate that this structure, built to accommodate a traffic unknown less than a century ago, should stand on *made* ground, for its whole site was not so very long ago covered by the ocean. The train shed is 602 feet long, 570 feet wide, and covered by one vast self-supporting roof, the trusses of which are of the cantilever type. The tracks are arranged in two decks, the long distance traffic coming in at ordinary level and the local traffic into the huge basement directly underneath and having a double track loop so that incoming trains may discharge their passengers, reload, and pass out without the usual trouble of making up a train, such a gain that a train can be discharged every minute. This two story arrangement of tracks is an innovation and a great saving, for while it cost but 6 per cent. additional to construct, it about doubled the capacity of the station.

The subway in which the local trains run is 7 feet below high tide, and the floor of this huge basement, about 10 acres in extent, is supported by 26,000 cedar piles, on top of which is placed a layer of concrete and ten layers of tar paper, each layer separated by tar compound. The whole is covered with an additional layer of concrete, making a water-tight floor nearly 3 feet in thickness. Around the sides, to shut off the water, a sheet piling made of plank 40 feet in length was driven, and the whole backed up by brick walls. The whole structure rests upon piles, of which 43,000 were used.

Compressed air with electric control operates the 250 single switches, the 37 double slip switches, the 283 movable frogs, and 150 semaphore signals. Two hundred signal lights are employed. The building in its highest part is five stories high, the decoration of the frontage and entrance rendering it not only imposing but beautiful. About 750 trains arrive and depart daily, and in 1900 21,000,000 passengers passed through its portals.

Some idea of the immensity of the structure can be gained from the fact that 150,000 square feet of glass, in which is imbedded a network of steel wire, was used for its roof. The wire not only makes the glass stronger and better able to bear up under loads of snow and ice but renders it possible to make it much lighter, a considerable item when the weight of the whole roof is taken into consideration. Sixteen million bricks were used in the structure and 200 acres of surface required painting, and the putty alone, 200 tons, weighs more than the fleet with which Columbus discovered America.

This station, costing $12,000,000, takes the record for the largest one on the continent from St. Louis, and is probably the largest in the world.



NICKEL STEEL INGOT CAST FOR THE TUBE OF 126-TON GUN.
Manufactured for the United States Army by the Bethlehem Steel Co.

MILITARY ART AND SCIENCE.

Evolution of Armor and the Different Processes — Contest between Armor and Gun — Projectiles — Evolution of the Metallic Cartridge — Evolution of the Rifle — Evolution of the Revolver — Automatic Pistols — Evolution of the Modern Cannon — The most Powerful Gun in the World — Rapid Fire and Machine Guns — Evolution of the Modern War Ship — "Constitution" Compared with the "Oregon" — Classes of Ships and the Work for which Each is designed — Torpedoes — Submarine Boats — Military Explosives — Smokeless Powder and Its Influence on Modern Warfare — Cordite — Lyddite — Gun Cotton — Nitroglycerin — Explosive Gelatin.

THE "Massacre of Sinope" called attention to the necessity of armor to keep out the destructive explosive shell which not only penetrated the ship's side but burst into fragments, killing and wounding those in its vicinity, while the powder charge which it contained set fire to everything inflammable. Then began a battle royal between the gun maker and the armorer with first honors for the armorer. The first thin plates of wrought iron armor were plainly superior to the gun.

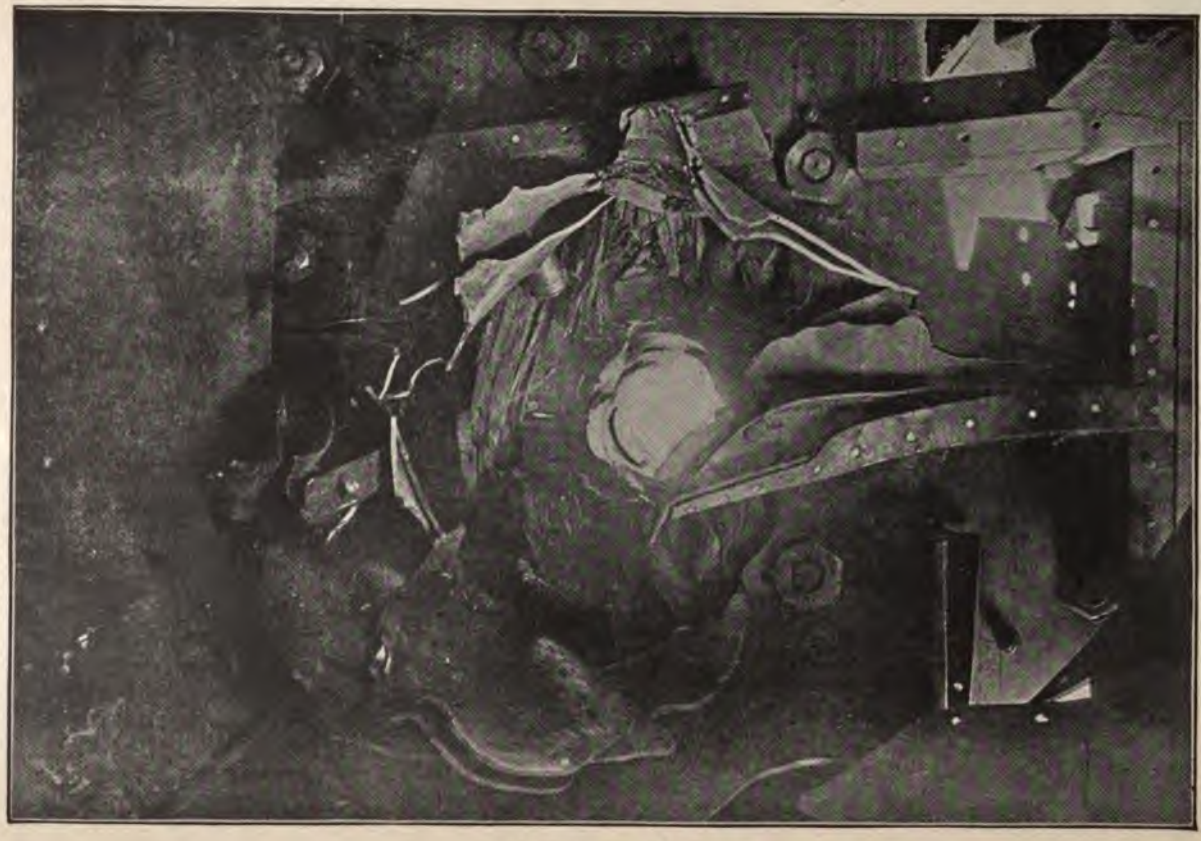
In the famous battle between the "Monitor" and the "Merrimac," the armor of neither ship was penetrated, and some of the American monitors employed in the Civil War received a great number of hits without being much damaged; *Weehawken* 187 hits, *Montauk* 214 hits. It was the gun maker's turn next and he produced a rifle cannon firing a long heavy cast iron projectile instead of a round shot. This penetrated the plate and scored the first victory for the gun. The armorer, seeing he must defeat the projectile by breaking

it up, welded a steel face over his wrought iron plate and produced "compound armor." The British warship *Inflexible* is to-day carrying 24 inches of compound armor. Her name is well chosen but it would be better if her armor were more elastic, for the development of the Palliser cast steel shot with a "chilled" point broke up compound armor.

The Siemens process of steel making rendered large masses of steel available for the armorer and it was used in place of iron. The gun maker replied with the steel projectile. Then came the addition of three per cent. to five per cent. nickel to the armor, making it tough and less likely to crack, only to be met in turn by a projectile to which chromium had been added, making it even tougher.

The Harvey process was the armorer's reply. It consists in placing the face of the steel armor on a layer of charcoal, covering the other side with a bed of sand, and subjecting the whole mass to intense heat for from five to twenty-seven days. The carbon from the charcoal penetrated the face of the armor an inch or an inch and a quarter and rendered it extremely hard, while the back of the armor retained all the toughness of the original steel. Armor then scored a decided victory, for Harveyized armor was easily superior in thick plates to twice, and in thin plates to two and a half times, its thickness of wrought iron.

The gun maker had not been idle but had called to his assistance the powder maker, and smokeless powder took a hand in the contest. This did not give such a severe strain to the breech of the gun and so required less metal there, and the gun maker applied the weight thus saved to the muzzle, changed the length of his gun from 30 calibers to 50 calibers, and with the progressive burning smokeless powder raised the velocity of his projectile and gave it a greater penetrating force. Meanwhile the armorer was not resting on his laurels. He was building enormous steel hammers, anncaling, re-



ARMOR VS. GUN.

A TURRET PROTECTED BY 15-INCH CURVED HARVEYIZED NICKEL-STEEL ARMOR, YET PENETRATED BY A 12-INCH ARMOR-PIERCING SHELL. VIEW INSIDE OF TURRET, LOOKING TOWARD GUN.

forging, and tempering his armor, thereby materially improving its resisting power.

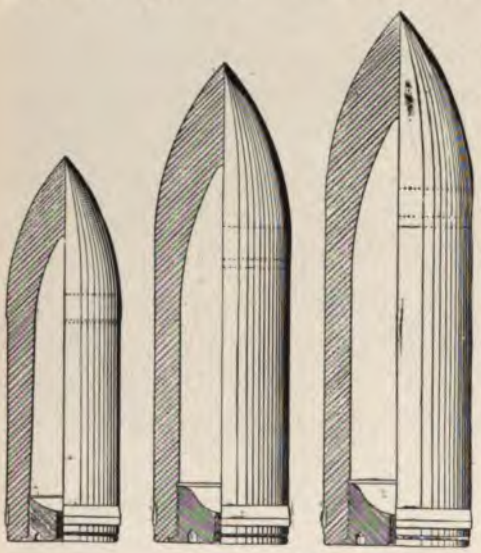
As an example of the expense connected with the manufacture of vast quantities of steel armor, the Bethlehem Steel Company bought of the Canet Company of France the right to use certain secret methods of armor making and built a 125-ton steam hammer, the largest one ever made, to reforge their armor. A comparatively recent improvement, called the Krupp process, has rendered this hammer obsolete and the investment a loss, for the armorer goes back a step farther and applies enormous hydraulic pressure to his steel while it is in a molten state.

To-day the short gun is obsolete and the speed of the projectile has been raised from 2000 feet to 3000 feet per second. The armorer has made it possible to give protection by thin armor to about all parts of the ship and has produced armor an inch of which is equal to 3.35 inches of wrought iron. On the proving ground, where armor and guns are tested under the most favorable conditions, the gun is able to penetrate the best armor, but the conditions of the proving ground are not those of battle. For example, by inclosing the hardened point of his projectile in a soft steel cap the gun maker increased his penetration 15 to 20 per cent. The armorer claims the steel cap is of advantage only when the shot strikes at nearly a right angle, and that at a greater angle, instead of being an aid, it is a hindrance.

The gun maker has derived great assistance from smokeless powder, but the recent armor made by the Carnegie Company according to the Krupp process, for the Russian battleship built by the Cramps Company, showed great resisting power. A high English authority says: "Our 12-inch gun perforates 36.8 wrought iron at the muzzle, but our best gun would hardly cut through the actual barbette plates of this ship. We should prefer to attack such a

ship elsewhere with common shell." If the fine, sharp point of the projectile can be preserved it renders the penetration of an armor plate much easier. If the face of the armor plate can be hardened until it will break up the point of the projectile it has achieved its purpose.

Capped or soft-pointed shot are popular in America; not so abroad. The cap is a piece of soft steel placed over the point of the shot with a layer of lubricant between them. On striking the armor the cap dishes it to its elastic limit and the shot passes through the cap aided by the lubricant and attacks the plate after the cap has pushed it as far as it will spring, and the plate has left only the local resistance. The cap further aids by tending to hold the steel in the projectile point together as the hoops about a barrel hold the staves.



FORGED STEEL COMMON SHELL.

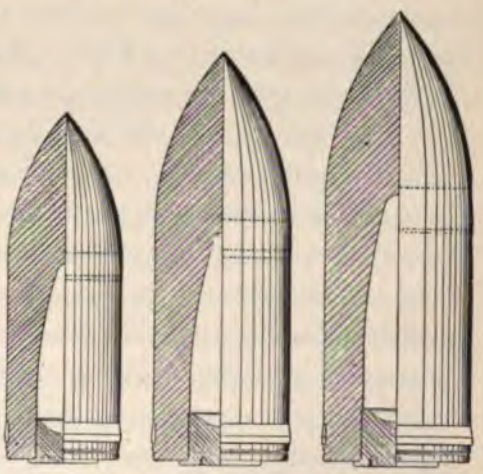
Projectiles for modern cannon are known as *common shell*, *armor-piercing shell*, and *shrapnel*.

Common shell are made of cast or drawn steel with thin walls so they will hold a large bursting charge. Fine grained black powder, rifle powder, is preferable as an explosive charge if used against woodwork, as it sets fire to it. Common shell are used against earthworks, buildings, or unarmored sides of ships. They won the victory at Santiago for "if a ship can be set on fire, riddled with small shot, driven to surrender in a few minutes by the attack of ex-

plosive shell on her upper structure, the protection of her so-called vital parts has availed her nothing. This [Santiago] indicates the great value of shell fire attack against ships which afford an opening for it." The following table gives weight of common shell and usual bursting charge:—

Gun	Weight of Shell	Weight of Bursting Charge
1-pdr. and 37 mm. R. C.	1 lb.	250 grains
47 mm. R. C.	3 lbs.	600 "
3-pdr.	3 lbs.	900 "
6-pdr.	6 lbs.	1450 "
4-in.	33 lbs.	2 lbs
5-in.	50 lbs.	3 "
6-in.	100 lbs.	3½ "
8-in.	250 lbs.	10 "
10-in.	500 lbs.	30 "
12-in. Cast Steel	850 lbs.	60 "
12-in. Forged Steel	850 lbs.	36 "
13-in. Forged Steel	1100 lbs.	50 "

On armor-piercing shell have been lavished the greatest care and the best mechanical ingenuity of the age. They are made of the best steel with special alloys, are reforged, annealed, tempered with acids, tempered in gas, capped with a soft nose; in short, every improvement that the ingenuity of man could devise has been expended upon them. The point is made extremely hard and the walls about the point heavy, growing thinner toward the base. The interior is bored out, to relieve the internal tension caused by forging, tempering, etc. An armor-piercing shell is expected to penetrate soft steel



FORGED STEEL ARMOR-PIERCING SHELL.

without losing its point or being materially deformed. The cavity is closed by screwing into the base a steel plug. To insure a tight fit in the gun a groove is cut around the base of the shell and into this a copper band is forced by hydraulic pressure. The shell is made nearly the exact diameter of the bore of the gun and the copper band somewhat larger. When driven by the explosion of the powder up into the bore of the gun, the copper, being soft, is forced into the grooves of the rifling, forms a gas-tight joint so the hot powder gases cannot escape, and as the projectile travels through the bore of the gun the copper band clings to the grooves and the lands of the rifling and gives the spinning motion to the shot which prevents it from tumbling end over end in its flight. The walls are so strong and the cavity so small in a shell designed to pierce heavy armor that the small charge of gunpowder it would hold is not likely to burst the shell. Some high explosives like jovite or gun cotton must be used if it is to carry an explosive charge. A single armor-piercing shell may easily cost from $300 to $500.

Shrapnel shell are named after their inventor, Lieutenant Shrapnel of the British army, who brought them out about the beginning of the nineteenth century. Shrapnel are made of cast steel with thin walls, the cavity filled with small leaden balls, packed in sulphur inclosing a small bursting charge of powder. Shrapnel is used against boats and exposed bodies of men, and the bursting charge is intended to explode before reaching the target, scattering the balls and driving them forward. The sulphur is used merely to hold the balls in place. Shrapnel is not very effective against men in trenches, but it makes them keep their heads down and so prevents a return rifle fire. Common shell are more effective on trenches than shrapnel, but men are not much more apt to be hit in firing position than when lying down, hence common shell do not keep down return rifle fire. Common shell loaded with lyddite were largely used in South Africa

but high explosives seem to waste the most of their energy in tearing the shell into very small bits, and lyddite shells were a disappointment. Against masses of men on open ground shrapnel is a particularly destructive charge.

Fuses. All shells may be exploded by a fuse either at the nose or at the base. The general classes are *time* and *percussion* fuses. A time fuse can be set so as to explode the bursting charge at any time after leaving the gun; percussion fuses are exploded whenever the projectile strikes an obstacle. Time fuses for shrapnel may be set at thirds of seconds up to fifteen seconds. Many styles of fuses are used and their action is too intricate to be described within the limits of this book.

The Gathmann shell, invented by Louis Gathmann of Chicago for firing gun cotton as a bursting charge, is made with a strong head and thin walls; the copper band is placed at the junction of the head and body of the shell instead of at the base, and the base is closed by a movable gas-tight plug or piston. When the gun is discharged the pressure drives the base plug against the gun cotton, and so the pressure within the shell balances the pressure on the outside and allows thin shells to be used, giving room for a larger bursting charge. The theory was not verified in the test for the shell burst before leaving the bore and wrecked the gun.

A special gun was ordered to further test the theory, which assumes that large quantities of powerful explosives bursting against a ship will wreck it. The experiments do not bear out the theory. A shell with thin walls certainly cannot penetrate any considerable thickness of armor, and 307 pounds of wet gun cotton lying right against a sample of the *Kearsarge* side armor was exploded and only burned the face of the plate a little. Chickens were placed at varying distances. One 43 feet away was struck by a piece of the shell and killed, but its feathers were not blown off; one just the other side of

the armor plate was not hurt at all. It was evident the explosion would have had no effect on an armored vessel or the crew within it.

The destructive effects popularly ascribed to high explosives have not been realized. In 1871, at the Stowmarket Gun Cotton Works, England, 27,000 pounds of dry gun cotton exploded. The noise of the explosion was heard for 30 miles, the shock was felt for 7 miles, yet a man standing on the railway 76 yards from the magazine was blown over a hedge, stripped of all his clothing, but uninjured.

Experiments with shells exploded in wooden boxes show that high explosives seem to waste much of their energy in tearing the shell into small bits. In general, then, a shell charged with gun cotton would break into the greater number of pieces and kill and wound more men, and the shell charged with gunpowder would break into larger pieces, which would cause more destruction to neighboring structures. Gunpowder also sets fire to anything inflammable, gun cotton does not.

The ablest authorities at present hold that gun cotton as a bursting charge has no advantages over gunpowder commensurate with the increased risk attendant upon its use. Further, it is not safe to fire with as high velocity projectiles charged with gun cotton, which means for them an increased trajectory and less chance of hitting the target.

Energy of Gun Fire. Two English writers, Lord Brassey and Admiral Colomb, each independently introduced in 1896 a new standard for measuring gun power of vessels, *i. e.*, "energy of gun fire per minute." The *power* of the gun is the force its projectile exerts. This force is termed energy and is measured by the number of tons it could lift one foot at each discharge, hence called foot-tons. The 32-pound carronade of Nelson's time had a velocity of 750 feet and its spherical shot an energy of about 125 tons. The new 12-inch

naval gun has a velocity of 2854 feet and its 850-pound projectile a muzzle energy of about 48,000 tons; *i. e.*, the force with which the projectile leaves the gun would be sufficient to lift that many tons one foot. Such is the progress of a single century. The new 4-inch rifle cannon has a projectile weighing 32 pounds, the same weight as that of the old carronade, but will penetrate as great a thickness of wrought iron at 1200 yards as the old carronade could penetrate of wood at its muzzle.

Velocity in foot-seconds means the number of feet a projectile flies in a second. Its rate of speed at the muzzle of the gun is called muzzle velocity. Sound travels 1100 feet a second, and a bullet from the best modern cannon almost three times as fast as sound. There are several reasons why high velocity is desirable. If the target is in motion a swift moving bullet will reach it before it has time to move far. All projectiles are deflected somewhat by currents of air, and the projectile that flies a given distance in the shortest time is deflected less than one moving slower.

The Penetration increases almost as the Velocity. It is a good "rule of thumb" that a projectile will pierce its caliber of wrought iron for each thousand feet of its velocity. For example, a 4-inch projectile moving a thousand feet a second would pierce a plate of wrought iron 4 inches thick. The same projectile moving two thousand feet a second would pierce a plate 8 inches thick. The greater the velocity the flatter the path of the projectile.

The Trajectory. The path in which the projectile travels is called its trajectory. A great deal of misinformation exists on this point, as well as confusion, as to the term "point blank." Projectiles are subject to the same force of gravitation as all other matter, and the "law of falling bodies" is operative here as elsewhere. If a projectile is in the air one second the force of gravity will cause it to fall 16 $\frac{1}{2}$ feet, and instead of moving in a straight line from the

muzzle of the gun to the point where it strikes it moves in a curve, *i. e.*, at its highest point, 16 1/3 feet above that straight line. If its flight occupies two seconds of time its curve will be greater, for gravity will then cause it to fall 48 1/4 feet, and the bullet at the highest point in its flight will be 48 1/4 feet above a straight line drawn from the muzzle of the gun to the point where it finally strikes. This curve is so great that at long ranges the marksman must be a good judge of distance or he will shoot over or under his target.

Explosives, no matter how powerful, cannot suspend the force of gravitation. They can only make the bullet travel faster and so in a flatter curve.

Danger space is that part of the path in the flight of the bullet that is neither too high nor too low to strike the target. It is evident then that a man standing where the bullet reaches the ground might be wounded in the feet; standing nearer to the gun he might be wounded in the head. The distance from the point where he would be struck in the feet to the point where he would be struck in the head is termed the "danger space." The higher the velocity, the straighter the path of the ball and the longer the danger space, and smokeless powder, by giving a higher velocity, has increased the danger space and rendered it less necessary for the gunner to be a correct judge of distance.

Rifling is the term applied to the spiral channels cut in the bores of modern small arms and cannon. The ridges of the metal within the base are called *lands*, the channels are called *grooves*. The lands cut into the projectile as it passes through the bore, force it to rotate as it follows the spiral of the lands and give it a spinning motion when it leaves the gun. Elongated shot are preferable to round because they offer less resistance to the air in proportion to their weight. If an elongated shot were fired from a gun with a perfectly smooth bore the shot would go tumbling end over end like

a club thrown from the hand, but if caused to spin rapidly as it leaves the bore it can be kept point first in its flight.

Shooting with rifles for prizes was practiced at Leipsic as long ago as 1498. A Swiss edict of 1563 prohibited rifling because it caused quarrels among contestants at shooting matches. Old rifles show that many were cut with grooves, so rifling was probably considered an aid in overcoming the difficulties of fouling caused by burnt powder and its value in preserving the point on flight of long projectiles not recognized until later. The process as applied to cannon is a comparatively recent one, dating from about the middle of the nineteenth century.

The Lancaster guns of England, which preceded the guns of Armstrong, instead of having a bore that was round, made the bore elliptical and twisted it to give the rotation to the projectile. The Whitworth rifling was an hexagonal bore twisted, with projectiles to fit. It was an improvement and accurate, but expensive to make. Lord William Armstrong was the first to successfully apply the present system of rifling to cannon. Armstrong's first gun was a breech loader with projectiles made of lead. Lead proved too soft and the projectiles were changed to cast iron covered with lead. This not giving satisfaction they were made of cast iron with studs or projections on them to fit into the grooves of the rifling, but when fired the studs broke up and the shot jammed and ruined the gun.

Compression Band. An American later brought forward the copper band now used about the base of the projectile and success was assured, for the band answered two purposes; it made the projectile slightly larger than the bore and being of soft metal was forced into the grooves of the rifling and gave the spinning motion to the projectile, while at the same time it made a gas-tight joint between the projectile and the bore of the gun and kept the powder gases from escaping until the projectile had left the gun. Rifling has

made possible the use of projectiles with a length five or six times their diameter.

Evolution of the Metallic Cartridge. In the flintlock musket a piece of flint held in the hammer was made to strike against steel so arranged that the resulting sparks fell upon powder within an appendage on the outside of the gun called the pan, and the flame was communicated from the pan to the powder charge within the bore. The device was clumsy, misfires were frequent, and the gun was useless in storms of rain or snow. The chemist was called to the aid of the soldier and showed him how to get fire from fulminate of mercury, "formed by the action of a solution of mercury in nitric acid on ordinary alcohol. It consists of very fine lustrous gray crystals which, when dry, are extremely sensitive to all kinds of shock and explode violently when struck, heated, rubbed, or pressed between hard surfaces." It was known to chemists long ago, but it remained for Bayen, army physician to Louis XV., to make known in 1774 its explosive qualities. Inventors at once began to experiment with it. Colonel Pauly of the French army in 1808 produced a cartridge containing the fulminate of mercury for its ignition. By 1818 the metal cap had been perfected. Percussion locks soon came into use and the piece of flint was discarded.

Cartridges were probably invented by the French, who wrapped the bullet and powder in a piece of paper and dispensed with the cumbersome powderhorn, leaving the cartridge to be ignited by percussion. In 1836 Lefrancheux, a French inventor, perfected a cartridge containing the bullet and the powder charge inclosed within a paper shell. The base of the shell was of metal inclosing a cap, and a small brass rod ran from the cap to the hammer of the gun. The rod, struck by the hammer, exploded the cap, which ignited the powder charge. By 1853 Flobert had perfected the small breech cap which bears his name, and a little later an Englishman, Ely, improved

upon the cap by filling it with gunpowder; but it was left for the Americans to bring the metallic cartridge to its present high state of perfection.

The Smith and Wesson Company, the manufacturers of the famous revolvers of that name, patented in 1854 the first central fire metallic cartridge containing the cap, the powder charge, and the lubricated bullet. This was used in their revolvers and was soon made applicable to all small arms. Prior to the metallic case the leakage of gas in breech-loading small arms had been a serious defect, but the metallic cartridge shell made the best kind of a gas check and overcame the difficulty. The process has grown until fixed ammunition is made for rapid fire cannon as large as the 6-inch gun with its hundred pounds projectile. In fact it made possible the rapid fire cannon and the machine gun, without which the battleship would be at the mercy of the torpedo boat.

"Prior to the Civil War all inventive thought was concentrated on the gun as the primary factor. But when the center-fire metallic cartridge was developed — presto! Science had put on its seven leagued boots. The change to the breechloader took place at a bound."

Importance of the Cartridge. "The ordinary notion is that powder and ball are mere accessories to the gun; that the gun is the all-important and substantive thing, while the cartridge is a minor incident. So all-prevailing has this idea been in times past that even the most expert have not only been influenced by it, but sometimes governed by it. The truth is the opposite. The cartridge is primary and antecedent, the gun secondary and consequent." *

The Evolution of the Rifle. In primitive times the weaker man must have shunned encounter at close quarters with a stronger an-

* Historical Sketch of the Ordnance Department, U. S. A., Major C. E. Dutton, U. S. A.

tagonist, and if "necessity is the mother of invention," the need of something to equalize his powers stimulated him to develop weapons that would kill at a distance. As his mechanical ingenuity developed he passed from throwing stones and clubs to the spear and the sling, and the bow and cross bow may not improperly be styled the early ancestors of the modern rifle.

Strange as it may seem, at a match held in England in 1792 between the long bow and the flintlock musket of the day, the long bow carried off the honors for accuracy at 100 yards. During the American Revolution it was once seriously proposed to arm part of the soldiers with bows and arrows because they were cheaper than muskets, could throw projectiles faster, and were nearly as accurate.

The "Brown Bess" was a famous flintlock musket introduced by William of Orange into the English army and used for a century and a half. With it Wellington won his victories and the British troops were armed with it until after the accession of Queen Victoria to the throne. It must have required a man of some courage to fire it without flinching, for the bullet was ¾ of an inch in diameter, weighed more than an ounce, and the charge was four and a half drams of powder. The cumbersome flintlock with which it was equipped allowed the priming powder within the pan to get wet, which rendered the gun useless in rain storms. Hence we see the peculiar aptness of Cromwell's famous injunction, "Trust in God but keep your powder dry." Further, it was some time after the trigger was pulled before the powder charge exploded and that rendered accurate holding and shooting difficult. Small wonder that officers exhorted their men to wait until they could see the whites of the eyes of their opponents before firing. Probably the old musket had a penetration of two or three inches of wood, and in those days a rail fence or a haycock made a breastwork not to be despised, while an antagonist at 200 yards distance was comparatively safe. With the

musket about one shot a minute could be fired and the necessary accompaniment of a soldier was a powderhorn, a bullet pouch, a ramrod, some wadding, and a piece of flint. The powder had to be turned into the gun, the bullet and wadding rammed down, the cover of the pan lifted, priming powder poured in, the trigger pulled, and the gun held on the mark until the charge exploded. In wet, drizzly weather the gun was useless as a firearm and became simply a "good handle to a bayonet." Indeed the bayonet was a weapon largely relied upon in those days.

To-day, the powderhorn, the bullet pouch, and the flintlock hang on the wall as curios or are found only in museums, preserved as mementos of the past. The modern soldier has a breech-loading magazine rifle that can kill a man at two and a half miles. The piece of flint has given place to a few grains of fulminate of mercury in a brass shell containing both the powder charge and the bullet. His ammunition may be soaked in water without affecting its efficiency and can be used in all kinds of weather. He is able to fire his rifle so rapidly that he cannot carry ammunition enough to last him an hour, and instead of two or three inches of wood affording protection to an enemy an ordinary tree in the forest is unable to do so, for his gun has a penetration of from 30 inches to 60 inches of wood. Bayonet charges in massed bodies are figures of speech or figments of the imagination. To attempt one would be suicide. The extreme range and great accuracy of the gun are fast turning the bayonet into a trowel for intrenching purposes. The new rifle has rendered a change in battle formations necessary. British grenadiers have been known to charge in such perfect alignment that a cannon ball has knocked the muskets out of the hands of nearly a whole file. To-day such tactics would be simply murder, and charges are made in short rushes, a few men at a time springing up, running a few yards and throwing themselves flat on the ground to escape the deadly fire.

Smokeless powder in long range rifles has rendered it possible for a comparatively small number of good marksmen under cover to inflict terrible loss upon opponents forced to attack in the open, as is evidenced by the late South African war. So deadly has rifle fire become that it may cause the adoption of bullet proof shields large enough to afford protection for a man's head and shoulders when lying prone. Such shields of steel plates an eighth of an inch thick have already been made in England for the Japanese navy.

The modern rifle has come up step by step until it is a weapon of extreme precision, for chance has been eliminated until it now plays but a small part; and what is progress but the elimination of chance?

The limits of this article will allow only a brief mention of the most prominent types in the development of modern small arms. Firearms were regularly introduced and issued to the English army in 1471, and for centuries the smooth bore was preferred to the rifle because, although not so accurate, it could be more readily loaded, for it was difficult to drive down a close fitting round ball in a rifle after it had been fired a few times without cleaning. Napoleon endeavored to improve the musket and detailed Colonel Pauly for that purpose, who in 1812 designed a breechloader with the swinging block. This was pronounced too complicated. Dreyser, who had worked in Colonel Pauly's shop, brought out in 1836 a gun which had a bolt driven by a spiral spring in place of a hammer. From it the Prussian needle gun was evolved and the needle gun was the parent of the bolt guns of to-day.

Eli Whitney, the inventor of the cotton gin, in 1798 began the manufacture of muskets for the United States. He undertook the work at the special request of Thomas Jefferson, secretary of state of Washington's cabinet. The improvements he made in connection with that work have perhaps been as beneficial to mankind

as his more famous invention. It was he that devised the system of hardened patterns, called jigs and templets, by which cutting tools are guided to make all pieces of work alike. It is by means of this system that the parts of all high grade machines are made interchangeable. "In presenting his views to Mr. Jefferson in reference to the feasibility of making all arms interchangeable, Mr. Whitney met with the most violent opposition, both English and French ordnance officers ridiculing the idea as an impossibility, and claiming that each arm would be a model and would cost, at least, one hundred dollars." Whitney proved his system practicable. "The English War Department was forced to adopt the same system, and put it to practical use in 1855 by importing a large amount of American machinery. Since that date other European governments have adopted the same general system, which is made specially necessary in the proper manufacture of breech-loading small arms. The admirable series of inventions used in this system of Mr. Whitney's remains now, like the cotton gin, the same as when first invented, no practical change taking place in eighty years, notwithstanding the inventive genius which has been at work during that period of time. No patents have ever been taken out for the Whitney inventions, but they have been freely given to the public, and have saved the United States government large sums of money by lessening the cost, and perfecting the manufacture and repairs of firearms." *

The Springfield Arsenal was opened in 1800, Whitney's system established, and the manufacture of the Springfield musket commenced, modeled after the French Charville flintlock. In fact, until the needle gun came out French models in firearms were everywhere pretty generally followed.

In 1811 the United States issued a patent to John H. Hall of North Yarmouth for a breech-loading rifle, and in 1816 one hundred

* "American Inventions." General Norton.

of these were made and issued to the army. This is worthy of note as being the first breech-loading rifle issued to any military body. It was used with great success in the Black Hawk and Seminole wars, and one special and significant advantage claimed for it was that the parts were interchangeable. This seems to have stimulated American inventors, for prior to 1860 more than two hundred patents had been granted for breech-loading small arms, and, with the exception of the needle gun, good authorities have claimed that every arm of a breech-loading system used in Europe is of American origin, many being of American manufacture. Indeed, in 1878, Mr. James Lee, an American inventor, submitted to an army board a plan for a solid or detachable magazine underneath the receiver of the gun. Prior to this all magazine guns had carried the cartridges under the barrel or in the stock. Mr. Lee's gun was in so crude a state that it could not be tested at that meeting, but made a favorable impression. It was patented in the United States and Europe. The idea found favor in 1879 abroad and it has come back to us under such foreign titles as Mauser, Mannlicher, Krag-Jorgensen, etc.

The Minie Ball. Between 1840 and 1850 Captain Minie invented the bullet of that name. It consisted of a hollow base with an iron cap which, being driven in by the force of the explosion, expanded the base of the bullet and made it fit the rifling. The British government paid him £20,000 for his invention and rifles became pretty generally adopted as military arms.

In 1853 the Enfield Rifle appeared in England. It was a composite gun embodying the good points of all submitted by the competitors who had hoped to have their models adopted. It was fairly accurate up to 600 yards, which at that time was considered a very long range. This gun is especially interesting because when issued to the native troops of India it caused the mutiny of 1857. The ball and powder being inclosed in a greased paper the natives were

led to believe that the lubricant was made from cows' and pigs' grease for the especial purpose of defiling all good Hindoos and Mohammedans. "The Hindoo regards the cow with religious veneration, and the Mohammedan looks upon the hog with utter loathing. In the mind of the former, something sacred to him was profaned; in that of the latter, something unclean and abominable was forced upon him."

In 1842 Prussia adopted an improvement of Dreyser's gun and it afterward became famous as the Prussian needle gun, and it is popularly credited with having been largely responsible for the success of Germany in her war with Napoleon III. In this model the hammer was discarded and a bolt resembling an ordinary door bolt with a needle-like projection took its place. The bolt closed the breech of the gun and was actuated by a heavy coil spring. The cartridge was made of strong paper and contained the powder charge and bullet. At the base of the bullet was a patch of detonating powder. When the bolt was drawn back it compressed the coil spring. When the trigger was pressed the bolt propelled by the spring shot forward, driving the needle through the charge of powder and striking the fulminate at the base of the bullet, which in turn ignited the powder charge. The bolt guns of the present are improvements of the needle gun.

In the Franco-German War of 1870 the Prussian needle gun was opposed to the French chassepot. A special interest is attached to the latter for it has been charged that Napoleon III. made a mistake in selecting it as a national arm and that its defects were in a large measure responsible for his defeat and downfall. It was a bolt gun with a bullet weighing 380 grains, propelled by 85 grains of powder. It had an extreme range of 1800 yards, which may have been the reason why it was selected, but even at 100 yards it was inferior to the Prussian needle gun in accuracy. In the face of the

successful use of metallic cartridges in the American Civil War, the cartridge employed by Napoleon was a weak paper one and when pushed into place by the bolt the walls frequently broke up and the cartridge exploded prematurely. No lubrication was provided for the bullet and after firing a few rounds it was often difficult to get a new cartridge into place.

In England, Sir Joseph Whitworth applied his peculiar style of a six-sided projectile fitting in a bore of the same shape to small arms. At the first meeting of the "National Rifling Association," July 1, 1860, Queen Victoria opened the tournament with a shot at 400 yards from a Whitworth rifle, resulting in a bull's eye within an inch and a half of the center. The rifle was considered accurate but too expensive.

The American Civil War strained the resources of the North to the fullest extent, and never before had a large army such a curious medley of weapons, and the confusion arising from the use of so many kinds of ammunition was serious enough. At the close of the war there were over twenty different kinds in service.

The Sharps rifle was one of the best and 100,000 of them were used. It was invented in 1848 by Christian Sharps, was improved, until, about 1857, it appeared as about the first practical breech-loading rifle. It was used in the Kansas struggle, where it was highly esteemed for the rapidity and accuracy of its fire. From it eight or ten shots per minute could be fired, making a regiment armed with it equivalent to two or three times their number armed with muzzle loading guns. It was a single loader.

The Spencer, patented in 1860, appears to have been about the first successful magazine gun. The stock was hollow and contained a tube running from the butt plate to the lock mechanism. This magazine would hold nine cartridges, and a spiral spring at the butt forced them one at a time up to the lock mechanism as needed. The

bullet was half an inch in diameter and weighed an ounce. The arm could be fired seven times in ten seconds and was used with great success in the Civil War. It was considered that men armed with it were equal to five or six times their number armed with muzzle loaders. When first used in battle it aroused great interest, the Confederates saying in joke that the Federals loaded all day Sunday and fired the rest of the week.

The Springfield rifle, adopted by the United States after the close of the Civil War, was several times improved until its manufacture was discontinued in 1892 upon the adoption of the Krag-Jorgensen. It is a single shot breech loader with a caliber of .45, an extreme range of 3500 yards and a velocity of 1300 feet with a 512 grain lead bullet. Thirty-four shots can be fired with it in two minutes. The objection to the gun is its heavy recoil and high trajectory, making the "danger zone" shorter, but beyond a thousand yards it has a striking force greater than any of the high velocity small bores, and at that range the wounds inflicted by it are more severe. Fitted with a smokeless cartridge it has been used in the Philippines and there preferred by some officers to the Krag.

The Krag-Jorgensen rifle was invented by Colonel Krag, chief of ordnance of Norway. The United States pays him a royalty of $1.00 on each gun. This is a 5-shot magazine gun of .30 caliber; weight of bullet, 220 grains; powder, 40 grains; extreme range, 4000 yards; muzzle velocity, 3000 feet. The bullet is a steel shell filled with lead to give it weight. The gun is accurate and can be used as a single loader, holding in reserve, for an emergency, the five shots in the magazine. The wounds made at short range by all small caliber guns of high velocity are frightful. As the range increases and the bullet loses its velocity the wound becomes a small clean puncture.

To-day all the armies of the great powers are equipped with

small bore high velocity rifles. There has been a steady decrease in caliber from the .75 Brown Bess musket to the .70 Minie, .57 Enfield, .50 Spencer, .45 Springfield, .303 Lee-Metford, .30 Krag, .275 Mauser, .236 Lee Navy. The latter caliber is too small and the United States navy has adopted the one used by the army.

The grooves of the early rifle had only a slight twist and the large caliber bullets were made of lead hardened with tin or antimony. With the introduction of more powerful charges and increased velocity it was necessary to increase the twist from the one turn in 22 inches of the Springfield, to the one turn in 10 inches of the Krag, to preserve the end on flight of the bullet. It then became necessary to cover the bullet with a metal stronger than lead to hold to the rifling and now a thimble-like shell of cupro-nickeled steel is pretty generally used with the inside filled with lead to give it the required weight. The rifles of the different nations are so equally matched

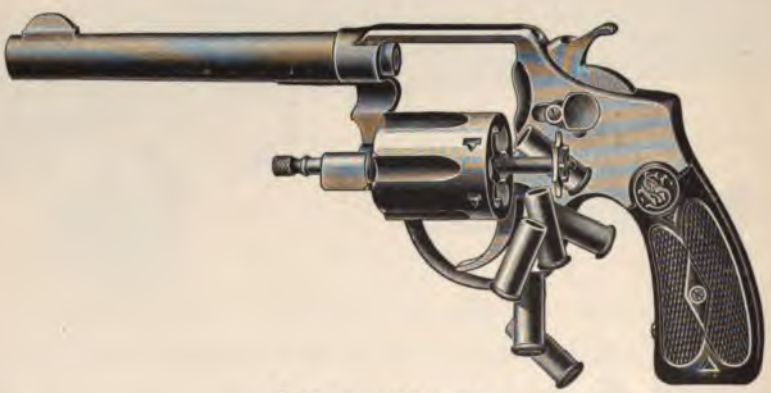
THE KRAG-JORGENSEN U. S. RIFLE CONTRASTED WITH OLD FLINT LOCK.

that any decided improvement in the cartridge of one might easily render that weapon superior in range, penetration, velocity, and accuracy to all the others. Any of them will penetrate, at a short distance from the muzzle, from 40 to 60 inches of pine boards and from one half inch to an inch of wrought iron. Although very accurate shooting cannot be expected of any of them beyond 1000 yards,

THE 17TH CENTURY.

THREE BARRELED ITALIAN FLINTLOCK REVOLVER LOADED WITH LOOSE POWDER AND BALL.

This weapon had to be primed each time it was fired and the barrels turned by hand. It was unserviceable in wet weather and had an effective, although not accurate, range of about 50 yards.



THE 20TH CENTURY.

THE LATEST MILITARY REVOLVER OF THE SMITH AND WESSON COMPANY.

This weapon uses fixed ammunition, can be fired faster than a shot a second, and is effective and accurate at a greater distance than were the muskets with which Wellington defeated Napoleon.

most of them have an extreme range of at least two miles, with sufficient remaining energy to kill at that distance.

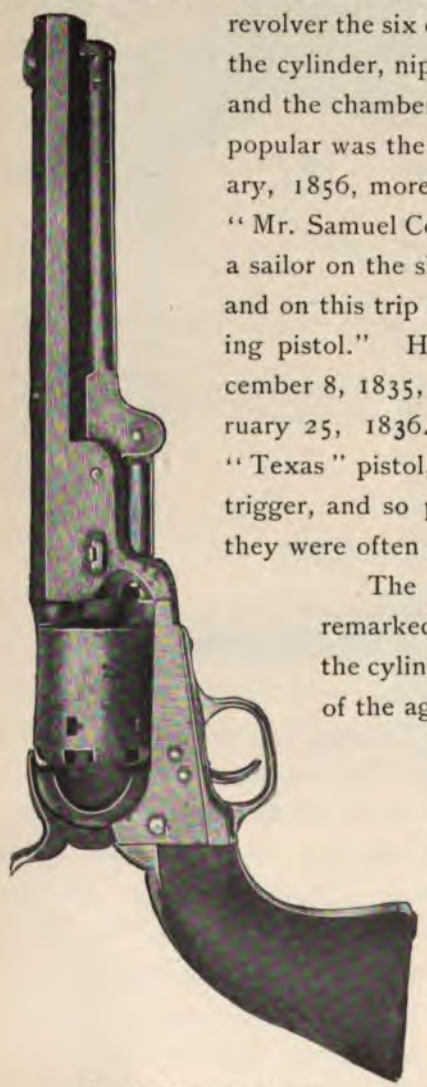
The following table shows the rifles used by the principal powers of the world. They are all bolt guns using bullets covered with a metal patch ranging in hardness from copper to steel:—

Country	Name of Gun	Caliber	Cartridges in Magazine	Sighted to	Muzzle Velocity
Austria-Hungary	Mannlicher	315	5	2133	2115
Belgium	Mauser	301	5	2190	1968
Canada	Lee-Enfield	303	10	2900	2200
China	Lee	303		2200	2400
Chili	Mauser	276	5	2400	2285
France	Lebel	315	8	2187	2190
Germany	Mauser	311	5	2242	2100
Great Britain	Lee-Metford	303	10	2900	2200
Italy	Carcano	256	6	2100	2320
Japan	Muratta	315	8	2800	1900
Mexico	Mondragon	256	8	2603	2362
Russia	Mannlicher	299	5	2500	
Spain	Mauser	276	5	2200	2285
Turkey	Mauser	301	5	2190	1968
United States	Krag-Jorgensen	300	5	2200	2300

Although the first practical working revolver was invented and brought out within the memory of men now living, the idea itself is half a thousand years old. A cut is shown of an Italian revolver of the seventeenth century and revolving firearms are even centuries older than this. The pistol shown in the cut has three barrels turning about a central pivot. The barrels were turned by hand and a spring catch held them in the proper position for firing. The application of the idea appeared toward the close of the fourteenth century and was so much in advance of its time that it had to wait five centuries for the metallic cartridge to be invented to complete its efficiency.

It remained for a Connecticut Yankee, Colonel Samuel Colt, to make his name a household word and bring out in 1835 the first

practicable revolver that could be used, having a cylinder that revolved when the hammer was drawn back. In the first Colt revolver the six chambers were bored nearly through the cylinder, nipples for percussion caps screwed in, and the chamber loaded with powder and ball. So popular was the arm that in ten years from January, 1856, more than half a million had been sold. "Mr. Samuel Colt, on August 2, 1830, shipped as a sailor on the ship *Carlo* from Boston to Calcutta, and on this trip made the first model of his revolving pistol." His English patent was issued December 8, 1835, and his United States patent February 25, 1836. The first revolver, called the "Texas" pistol, was a .34 caliber with a concealed trigger, and so popular in Texas and Mexico that they were often sold for $100 each.



COLT'S FIRST REVOLVER.

The chambers of the Colt revolver, as remarked, were not bored entirely through the cylinder, and it took the inventive genius of the age another twenty years to remove the last quarter inch of metal. Rollin White finally accomplished this and to him a patent was issued April 3, 1855, for a cylinder open from end to end. White had intended to load each chamber with powder and ball, close the rear end with a wad having a hole in its center for the fire from a percussion cap fixed on the frame to pass through and ignite the powder charge. The said fire had an

inconvenient way of passing to more than one chamber at once and his plan was not a success. Smith and Wesson secured his patent and in 1860 produced the first practicable metallic cartridge revolver ever made. Their revolvers are unexcelled in accuracy, quality of material used, and beauty of finish.

The Smith and Wesson and the Colt revolvers are easily the best in the world. The larger models of either of these will in the hands of an expert make a better target at 200 yards than the Springfield rifle in the hands of the average militiaman. Many difficult mechanical problems are encountered in the manufacture of the revolver, for the joint between the cylinder and the barrel can never be made gas-tight, and it is difficult to always bring the chamber of the cylinder into perfect alignment with the bore, at the moment of firing. Although the principle on which the revolver is built is thus defective, it is surprising to see how closely mechanical ingenuity has approximated the ideal and produced a weapon that is deservedly popular.

Automatic Pistols. The automatic pistol made its appearance not long after the automatic machine gun. The first were the Mannlicher and the Mauser, each patented in the United States in 1897. These have the magazine underneath the barrel, in front of the trigger. They use smokeless powder and metal jacketed bullets, have a high velocity and great penetration with an extreme range of more than half a mile. The gas pressure at each discharge furnishes the power to eject the shell, reload the weapon, and cock the piece ready for another shot. The heavy trigger pull, which seems a necessary accompaniment of these pistols, is not conducive to extreme accuracy; they are essentially military arms and have not the extreme accuracy of target pistols and revolvers. They are widely used by officers of the German army and to some extent by those of the British.

The automatic Colt pistol, a later pistol of American invention, is of the Browning patent, manufactured in France by a French company and in America by the Colt Patent Fire Arms Manufacturing Company of Hartford, Connecticut. This weapon is made in two calibers, .38 and .32, using a special rimless cartridge with a jacketed bullet. In the larger caliber it has a muzzle velocity of about 1300 feet per second and a penetration of about 11 inches of pine. The magazine is in the grip and contains seven cartridges, and the seven can be fired in $1\frac{2}{5}$ seconds. The arm is remarkable for its extreme

HALF SIZE.

COLT AUTOMATIC PISTOL.

simplicity and the small number of parts, and is probably as accurate as the average military revolver. To operate the weapon the slide covering the barrel is drawn back and a spring returns it to its former position. These movements cock the weapon and insert a new cartridge. A pull of the trigger releases the hammer and discharges the piece. A slight portion of the recoil is utilized to eject the cartridge, cock the piece, and load a fresh cartridge in position ready for firing. Each discharge leaves the weapon ready for firing as long as there is a cartridge in the magazine. The pistol is provided with safety devices that insure safety in handling. The manufacturers have apparently considered it wise to fit it with a fairly heavy trigger pull until the public become accustomed to it.

Evolution of the Modern Cannon. The first appearance of can-

non is enveloped in the gloom of the Dark Ages. Some of the earliest cannon were made of bars of iron held together by hoops, much like the staves of a barrel. All of the earliest forms were crude in the extreme, were not mounted on carriages, and were rolled about like saw logs. When in action the breech rested on the ground, the muzzle was propped up with blocks. After the application of trunnions or arms to cannon, the date of which is uncertain, they could be mounted on wheels, moved, and aimed.

OLD CANNON OF GORDON'S BATTERY, SEVASTOPOL.

Moors Introduce Artillery. There is evidence to show that the Moors were the first to introduce cannon into Western Europe and they are said to have been employed against Saragossa, A. D. 1118. Cannon were used by Henry III. of England against the Duke of Gloucester in 1267, by the Spaniards against Cordova in 1280, and the expense account of Edward III. of England (born 1312, died 1377) shows that cannon were used in his wars. Ferdinand IV. of Spain used cannon when he captured Gibraltar in 1309.

Nelson's Flagship. In few things does the progress of the century show more marked improvement than in military arms. The *Victory*, Nelson's flagship, the most famous of British men-of-war, carried thirty 42-pounders and 32-pounders, thirty 24-pounders,

forty 12-pounders and two short 68-pounder carronades. All these guns were simple cast iron tubes. They were placed on clumsy wooden carriages mounted on low wooden wheels or trucks. The breech of the gun was purposely left heavy and the gun elevated or depressed by prying up the breech with handspikes and putting a wedge-shaped block of wood under to hold it in the right place. The same handspikes moved the entire carriage about to point the gun left or right. The recoil was not controlled, only limited, by a stout rope called a breeching running through a ring in the end of the cannon, the ends being tied to ring bolts in the ship's side. Each time the gun was fired it recoiled as far as the breeching would permit, was then loaded and by means of tackle and handspikes shoved back into place for another shot. Mechanical progress had not reached the stage where it could give a close fit to the bore of the gun and the projectile. The latter, simple, round, cast iron, solid shot, taken just as they came from the foundry, frequently fitted so loosely that if the muzzles of the guns were depressed they would fall out, and a roll of the ship might leave half the guns of a broadside loaded only with the powder charge. When fired, the loosely fitting shot went bounding from side to side through the bore of the gun, and the side by chance hit last determined the direction of its flight. The range was so short and the guns so inaccurate that Nelson, in 1801, reported adversely on a plan to put sights on them, saying, "I hope we shall be able to get so close to our enemies that the shot cannot miss the object." Every operation was performed by the simple and direct application of manual labor and fourteen men comprised a full gun crew for a 32-pounder. To-day, aided by modern appliances, twelve men will man two 13-inch guns in the turret of a battle ship handling guns and carriages weighing 180 tons and steel shell weighing 1100 pounds.

"Constitution's" Guns. The most powerful gun on the famous

Constitution was a 32-pounder, not differing materially from those on Nelson's ship. It appears to have cost about $375, which would just about pay for one forged steel armor-piercing shell, weighing 1100 pounds for a modern 13-inch rifle. The extreme range a century ago was about three miles. To-day the extreme range of the 16-inch rifle is over twenty miles and the cost of firing it once is $865.

Even fifty years ago the long 68-pounder was about the best gun and its cast iron spherical shot could strike a blow at 1000 yards equivalent to 452 tons. To-day the blow from the shell of a 16-inch rifle is equivalent to 88,000 tons, and a bursting charge may be carried with it sufficient to wreck the machinery of the stoutest battle ship afloat. It will be interesting to note the principal steps in military progress leading up to this modern giant.

Evolution of the Modern Gun. Military service owes a large debt to Gribeauval, chief of the French artillery in 1765. At that period field guns were so rude and heavy as to now seem almost worthless. He reduced their weight and made it possible to move them about; among other numerous improvements he fitted the shot to the bore more accurately, thus increasing the gun's range and rendering it far more effective. His system, adopted in 1774, made the French artillery of the next generation superior to any in the world. Napoleon himself was an artillery officer of the Gribeauval school.

Prior to 1812 hollow shot filled with an explosive to burst the shell into pieces and increase its destructive effect had been fired only from mortars. These were short guns throwing a shot high into the air with the expectation of its falling upon or near the target. Colonel Bomford in 1812 devised a long-chambered gun by means of which shells were fired directly at the object. This was called a "columbiad." The idea was not further developed in America, but General Paixhans, a celebrated artillerist of France, brought up

in the school of Napoleon, carried the idea further, and in 1819 perfected it. Explosive shells from Paixhans guns used at the Siege of Antwerp, 1832, were effective. Paixhans was an engineer of great merit and much in advance of his time. He advocated the application of steam and armor to battle ships. Critics of other nations ridiculed his plans mercilessly, saying, "He jumps to the conclusion that steam vessels having begun by being servants to the line of battle ships will in the end become their masters." "His suggestion of vessels shielded with iron to afford security against the effects of shells fired horizontally, only shows that speculative theoretical ideas when exerted in pursuit of a favorable object may be carried so far as to refute themselves."

Progress Arrested. Paixhans had tried his guns on the hull of an old ship and his own countrymen believed in him so much that in 1830 the French had nine steamships armed in part with Paixhans' new guns. By 1850 the gun had progressed as far as the mechanical skill of the age would permit. In 1844 a 12-inch wrought iron gun burst on board the United States war ship *Princeton*, killing the Secretary of State, the Secretary of the Navy, and several others. The material was proved defective, but iron makers at that time could not produce wrought iron in large quantities that would sustain the shock of fine grained powder. Rodman removed that difficulty.

In the fifties Krupp, the famous gun maker of Germany, and Lord William Armstrong of England, each tried to make steel guns. Lord Armstrong has said that it was only after eight trials that he was able to find a piece of steel weighing 350 pounds and 6 feet long that did not develop flaws when boring it for a gun of 1.88 inches caliber. The art of steel making was at such a low state that he was "obliged to accept the fact that steel was not yet ripe enough for the process of gun making, and was compelled to use wrought iron."

Rodman and Initial Tension. To General Rodman is due the discovery of the principle of initial tension. Molten iron or steel in cooling tends to cool first on the outside and leave hollows and flaws in the center (see "Piping" under Steel Manufacture) causing internal stresses within the mass. General Rodman conceived the idea of casting the gun hollow and cooling it from the inside. It worked well and the Rodman cast iron gun was the best of its kind in the world. There is now in one of the parks of Brooklyn a Rodman gun with a 20-inch bore.

Steel manufacture improved somewhat with the Bessemer process and gave large masses of steel from which guns with a steel tube clasped by wrought iron bands were made. The Siemens Open-Hearth Process of steel making, giving yet larger ingots, made it possible to use steel for the whole gun.

Our present cannon is made upon the "built-up" principle and consists of gigantic steel tubes or hoops expanded by heat and shrunken over each other. The principal parts are the tube, a hollow steel forging extending the full length of the bore; the jacket, covering about two fifths of the tube; the jacket hoops, shrunken over the jacket; and the chase hoops, shrunken over that part of the tube in front of the jacket.

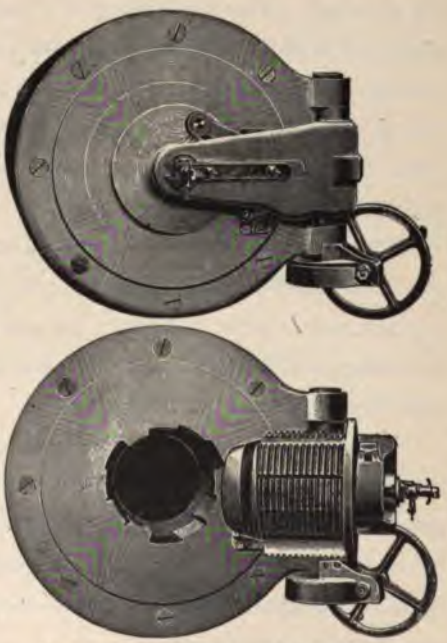
Principle of Initial Tension. This method is an application of Rodman's idea of initial tension. Suppose a half dozen hoops were placed one within another and fitting closely. An expansive force exerted within the inner hoop would burst it before much stress fell upon the next hoop and the stress being delivered from one to another successively, hardly more force would be required to burst all the hoops than to burst any one. Suppose another arrangement of the hoops, by which the inner hoop is clasped by the second and the second clasped tighter by the third, and so on to the outer one. The expansive force then exerted within the innermost hoop must be suf-

ficient to burst all of them combined. The built-up gun is based on that principle. "It is generally conceded that no possible thickness can enable a cylinder to bear a continual pressure from within *greater on each square inch* than the tenacity of a square inch bar of the same material; that is to say, if the tensile strength of cast iron be 12 tons per square inch, no cast iron gun, however thick, could bear a charge which would strain it beyond that point; for on the first round the interior layer would be ruptured before the outer portion could come into play, and every succeeding round would tend to make matters worse."*

The Steel in a Gun must be of the Best Quality. In battle the gun may be hit by projectiles; in firing, the rifling will be subjected to enormous stress, and the gases formed by the exploding powder have a destructive effect upon the steel. The United States uses steel made by the "Siemens Open-Hearth Process," subjected to the Whitworth process of fluid compression. When the steel is melted it is poured into a strong cylinder and subjected to hydraulic pressure, which squeezes out the gas or air bubbles within the casting and makes the metal much denser and devoid of flaws. Severe tests of the metal are made, and it must stand pressure of from 46,000 to 50,000 pounds to the square inch, without a permanent change in form. In its test for tensile strength it must stretch at least 15 per cent. before giving way under a stress of from 70,000 to 100,000 pounds to the square inch depending upon the part of the gun for which the steel is to be used. The "tube" is cast solid, then bored and a heavy steel shaft (mandrel) passed through on which the tube is subjected to hydraulic pressure or hammer forging to enlarge and elongate it. It is then roughly finished, tempered in oil, and sent to the gun factory. Tempering makes the steel tougher, adds to its tensile strength, and makes it more elastic and harder. Upon arriving

* Ingersoll "Text Book of Ordnance and Gunnery."

at the factory the tube is put into an enormous lathe and turned to exactly the required diameter, then placed upright in a pit adjoining a furnace wherein the jacket is to be heated. The jacket is carefully bored out until its inner diameter is slightly smaller than the outer diameter of the tube. It is placed within a chamber, where it is heated by air blown through a white hot furnace burning crude oil. It is subjected to this for about twenty-nine hours until its temperature is raised to about 600 F. It is carefully measured to see that it is expanded enough to go over the tube, seized by a powerful crane, raised, swung and lowered over it at about the rate of a foot a minute until it clasps the rear part of the tube and extends back of it far enough to form the screw box which is to contain the breech mechanism. When in the desired position, the interior of the gun is cooled by streams of water circulating through the bore. When thoroughly cool it is replaced in the lathe, the other parts carefully turned to a new diameter and the other hoops shrunk on. Each process is expensive and requires the greatest care and highest skill.



BREECH BLOCK, CLOSED AND OPEN.

The breech of the gun is closed by a steel plug threaded and screwed in. The accompanying cut shows a Weling type of breech mechanism for a 12-inch gun. The inner part of the jacket that projects over the rear of the tube is cut away into a series of steps, as shown in the illustration,

and in all but the deepest of these screws threads are cut. The breech plug has a corresponding series of steps and threads. There are three blank places in the screw box and three on the breech plug. When the plug is swung into position coinciding with the bore of the gun, it can be pushed directly into the screw box, and when given a turn of one twelfth its diameter, the threads of each step of the breech plug interlock with the threads of the next higher step of the screw box and the breech is securely closed.

Reference to the cut shows the breech plug with a round head and a dark ring separating it from the threaded portion. The head is a mushroom-shaped piece of steel and is allowed a slight to-and-fro motion. The dark ring is a pad composed of 65 parts of asbestos and 35 parts of pure mutton tallow. The explosion within the powder chamber forces back the steel mushroom against the pad, which under pressure is forced out at the sides and forms a gas-tight joint that prevents the escape rearward of the gas from the powder chamber.

The Weling system is an improvement over the old styles that cut away half of the threaded portion, for it gives a greater bearing surface and allows a lighter breech plug, easier to handle, requiring but one twelfth of a turn to unlock and affording a material gain in rapidity of action of loading.

The earliest cannons were breechloaders, but the system was discarded because the mechanical art of the age was not equal to producing a gas-tight joint. The modern mechanism is the product of the last half century. The gun is fired through a vent in the mushroom stock, and either a friction primer or an electric firing apparatus can be used.

The most Powerful Gun in the World. On April 7, 1900, at the Watervliet Arsenal, a record breaking feat in mechanical engineering was performed and the jacket shrunk upon the most powerful

gun in the world and one that is likely to hold that record for a long time. The shrinking was a most delicate operation. The gun, without jacket, weighed 102,000 pounds, the jacket 76,000, and the difference between outside radius of the gun itself and inside radius of the jacket after heating was only six one hundredths of an inch. To lift the 34-ton mass of hot steel out of the furnace, swing it up over the gun and lower it safely into position was not an operation to be attempted by novices. Any inequality in heating, an error of the merest fraction of an inch in measurement, or the least variation of alignment between the axis of the hot jacket and the tube in the pit during the operation of assembling, would have ruined the result of months of preparation.

The 16-inch gun consists of a forged steel tube, 49 feet 6 inches long, on which are first shrunk what are known as the chase hoops, hollow steel cylinders extending from the muzzle nearly back to the trunnions. Back of the chase hoops comes the jacket, on the forward end of which is placed the locking ring. Back of this on the jacket are placed the jacket hoops. Thus the rear third of the gun is of four thicknesses, the middle of three, and the muzzle end of two.

The total weight of the gun is 126 tons, its length 49 feet 6 inches, the diameter of the breech 6 feet 2 inches, the bore 16 inches, and the theoretical range 20.76 miles. To attain this range the highest point of its flight is five miles, or as high as any mountain in the world. The total weight of forgings for the gun as received from the steel works was 358,000 pounds. Finished, the gun weighs about 282,000 pounds, leaving 76,000 pounds of steel removed from different parts during manufacture.

The projectile for this gun is 64 inches long, and requires a powder charge of 1060 pounds. A pressure of 36,000 pounds to the square inch is developed at discharge. The cost of one round

for the gun is $865. The breech mechanism of the gun is beautifully simple. A few turns of a crank just below the breech on the right side does all the work of withdrawing and swinging back the breech block, which weighs not less than a ton.

Great Guns of the World. It was once planned to have eighteen of these gigantic guns defend the entrance to New York harbor, but the 12-inch gun has been improved so much that it is probable this monster gun will be the only one of its kind manufactured. Other nations have made guns of larger caliber but not so powerful; Italy one of 17¾ inches, France 16½ inches, England 16¼ inches, but in range, weight of projectile, and force of the blow the Watervliet gun surpasses them all. The advocates of the gun claim that no ship afloat can stand the terrible crushing effect of one of its projectiles, while their opponents say the gun is too expensive and that it is extremely unlikely that a ship in motion could be hit by it.

Recoil. When in the chamber of a cannon there is exploded half a ton of powder behind a projectile weighing more than twice as much, the effect is terrific and the backward pressure from it is as great as the force that moves the projectile forward. If this force were not controlled in a gun mounted on a ship it would tear the ship apart or drive the gun through the deck.

The cannon of holiday occasions with which the boys are familiar have projections or arms called trunnions on which the guns rest, but no trunnions ever forged could unaided withstand the recoil from a large cannon, and even if the trunnions held they would only tear the deck out of the ship. The 16-inch gun recoils with a force sufficient to raise 88,000 tons one foot, for it throws a projectile weighing as much as a team of horses higher than the highest mountain in the world and twice as far as from Albany to Troy. More space can be given to a gun on land than in the crowded turret of a ship and various means of counteracting the recoil that might be

serviceable for guns in forts would not do on ships. This backward motion of the heavy guns of a ship is intended to be stopped within a distance not exceeding three times the diameter of the gun's bore. The 13-inch gun, then, will be allowed to recoil no more than 39 inches. The recoil is controlled by means of pistons working in "recoil cylinders." The 13-inch gun in the cut has four recoil cylinders fastened to the sleeve, with piston rods fastened to the rear of the gun. The piston head is attached to the piston rod and is in the front part of the cylinder when the gun is fired. The recoil cylinders are stationary. When the gun is fired it slides back in the sleeve and draws the piston rod and head back through the cylinder. The cylinders are filled with water for the heavy guns and a mixture of water and glycerine for the lighter ones. Grooves are cut in the inner surface of the recoil cylinder and as the piston head starts back the water passes through the grooves, but in the back part of the cylinder the grooves grow shallower until they disappear, the resistance to the piston head becoming greater and greater until the gun is brought to a stop with a recoil of only three times its caliber. The water in front of the piston head escapes at 600 pounds pressure through a valve and a hydraulic engine forces water into the cylinder in the rear of the piston head, which drives it to the front of the recoil cylinder and returns the gun to its former position "in battery." The number of cylinders and their positions vary with different guns but the principle is the one most often used for the large ones. Some guns recoil up an inclined path and return by force of gravity. Rapid-fire guns frequently use the piston principle with recoil springs to return the guns to place instead of a hydraulic engine.

Heavy guns used for harbor defense are now mounted on disappearing gun carriages. In the Buffington-Crozier carriage the gun is held on four long arms moved by hydraulic or pneumatic machinery.

It is loaded beneath the level of the parapet over which it is raised, remains but an instant to be fired, and then disappears from sight. On this carriage the 12-inch gun can be pointed in a complete circle in 1¾ minutes and the gun has been fired nine times in fifteen minutes, aiming when depressed, and making a good target. Disappearing gun carriages, mines, and heavy breech-loading mortars have increased materially the resources of the defense. The disappearing carriage is at present receiving considerable criticism.

Modern mortars differ from breech-loading rifles only in length. They pass through the same processes of construction, load at the breech, and are rifled. They fire explosive shells at a high angle. The shell is expected to describe a huge curve and descend upon the practically unprotected deck of the attacking ship. The thick armor of a ship is carried on the sides to withstand direct fire; the limited amount of armor a ship can carry makes it possible to give but little protection against vertical or "plunging" fire.

MORTAR BATTERY IN NEW YORK HARBOR.

The 12-inch mortars defending the harbor of New York (see cut) are placed in pits beneath the surface of the ground. Their location is unknown to the general public and there is nothing visible at a distance to indicate their presence. The field defended is laid off into a series of imaginary squares, and the gunner in the pit trains the mortar to bear upon any particular square as directed. It is not necessary that the gunner see the enemy; his movements can be directed from a distance by telephone. The mor-

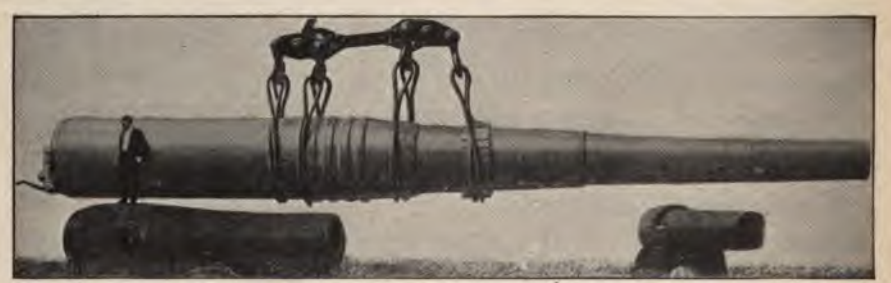
tar throws a shell 12 inches in diameter, weighing 1000 pounds, carrying within it a bursting charge of 100 pounds. They fire at an angle of from 35° to 65° and have an effective range of five or six miles. This half ton of steel falling from the clouds would easily penetrate the protective deck of any ship afloat, and even if it didn't explode in the magazines or machinery compartments, would pass on through the bottom of the ship.

With the old style gun, the crew at each discharge must get out of the way of the recoil, a wet sponge must be run through the guns after each shot to put out any lingering sparks of fire before placing the powder charge, the charge and the shot must be rammed down by hand, the gun run out by tackle and handspikes, pried about until it pointed as nearly right as they could guess, and after all these operations had been performed, fired with a hot iron or a match. Now, ammunition for rapid-fire guns is put up in metallic cases like revolver cartridges, the sponge is not required, the barrel of the gun alone recoils, the sights have been removed from the barrel and placed on the carriage, and the gun pointer simply keeps his sights on the target, pays no attention to the loading of the gun, and squeezes an electric bulb when the gun is ready to be fired. The new gun fires twenty or thirty times as fast as its old type.

The great weight of breech mechanism, powder, and projectile precludes making rapid firers of the extremely heavy guns, but the reduced weight of smokeless powder with lighter and simpler breech mechanism has brought improved 6-inch, 8-inch, and 9-inch guns into this class. On the Chilian cruiser *Blanco Encalada* four rounds were fired in 62 seconds from an 8-inch gun and the ammunition taken from the magazine below the protective deck. In the English navy a crew at drill fired an Elswick 8-inch gun three rounds in 28 seconds. On board the *Royal Sovereign* a 13.5-inch gun was fired seven rounds in twelve minutes, making six hits on a target at a range

of 1600 to 2200 yards, while the ship was steaming at eight-knot speed. A similar gun on the *Empress of India* fired four rounds in six minutes.

Range. The effective range and the extreme range of great guns differ widely. Guns on board ship cannot give extreme elevation of more than 17° for the portholes are not large and the gun in its recoil would strike the deck. The effective range there is about six miles. On land guns may be given a greater elevation with nothing in the way of their recoil, and the 6-inch gun may have a range of 7½ miles; the 8-inch, 9 miles; the 10-inch, 11 miles; the 12-inch, 11½ miles.



16-INCH RIFLE MADE AT WATERVLIET, THE MOST POWERFUL GUN IN THE WORLD. Compared with 20-inch Rodman gun (at the right) and 300-pound Parrott gun (at the left). Courtesy of the *Scientific American.*

Several years ago, on Krupp's range at Essen, Germany, a 9.45 Krupp gun with an elevation of 45° attained a range of 12.42 miles. In its flight the projectile rose 4.6 miles above a straight line and at this point the highest range of mountains in America interposed between the gun and its target would not have intercepted the flight of the shot. At Shoeburyness, England, in 1888, the year of the Queen's Jubilee, a 9.2-inch wire wound gun threw a 380 pound projectile with a muzzle velocity of 2360 feet an extreme range of 12.4 miles. It is believed that the 16-inch rifle from the Watervliet

Arsenal will throw its 2370 pound projectile propelled by 1060 pounds of powder with an initial velocity of 2300 feet a second, nearly 21 miles, the projectile in its flight reaching a height between 5 and 5½ miles above a straight line. Such shots are fired only for experimental purposes. With the target in motion the range must be much shorter to do effective work.

"**Large-caliber Gun Firing is pretty Expensive Work.** According to recently published figures for same a 13-inch gun firing an 1100-pound shell consumes 550 pounds of brown prismatic powder, costing for a single discharge $165. The common 13-inch shell is said to cost $116.63. Armor-piercing projectile costs $418. To these items must be added cartridge box, primers, freight, etc., amounting to about $15, or $296.63 for the common shell discharge and $588 for the discharge of an armor-piercing projectile. As the 13-inch gun can be fired about twenty-five times in an hour, the work of one gun for an hour may cost the government $15,000. The 8-inch gun costs about $65 for each shot; the 5-inch rapid-fire costs $33; the 6-inch breech loading shot costs about $40, $14 being for the powder; and each round of a Hotchkiss 6-pounder gun is estimated to cost $5.70, and a 1-pounder, $1.12. Whitehead torpedoes cost $3100 each."

When an elongated form was substituted for a spherical one it greatly increased the weight of the projectile. The old 32-pounder was a 6-inch smooth bore gun with an energy not often exceeding 200 tons. It would not shoot as far or as accurately as the rifle of the modern soldier. The 32-pounder of to-day is a 4-inch rifle cannon having a muzzle velocity of 3000 foot-seconds and capable of perforating 2¼ inches of the best armor at 3000 yards. The 6-inch gun, corresponding in caliber with the old 32-pounder, uses a 100-pound projectile having a muzzle velocity of 2900 foot-seconds ar
muzzle energy of 5800 tons, and is capable of penetrating m
four inches of the best armor at 3000 yards. The follo

shows the elements of the 1899 models of naval guns using smokeless powder and uncapped armor-piercing shells striking at right angles to the target.

Calibers of Guns	3-inch	4-inch	5-inch	6-inch	8-inch	10-inch	12-inch
Length .....calibers	50	50	50	50	45	40	40
Weight .....tons	0.87	2.56	7.4	8	18	33.4	52
Weight of projectile ...pounds	14	32	60	100	250	500	850
Muzzle velocity...foot-seconds	3,000	3,000	2,900	2,900	2,800	2,800	2,800
Muzzle energy ..... foot-tons	874	1,999	3,503	5,838	13,602	27,204	46,453
Perforation at muzzle, Harveyed nickel steel ....inches	4.19	6.12	7.51	9.35	13.57	18.57	23.42
Perforation at muzzle, Krupp armor ..... inches	3.35	4.90	6.01	7.71	10.66	14.86	18.74
Remaining velocity at 1000 yards ..... foot-seconds	2,328	2,477	2,460	2,516	2,531	2,587	2,619
Perforation at 1000 yards of Harveyed nickel steel, inches	2.98	4.77	6.03	7.74	11.86	16.71	21.42
Perforation at 1000 yards of Krupp armor .....inches	2.38	3.91	4.82	6.19	9.49	13.37	16.84
Remaining velocity at 2000 yards ..... foot-seconds	1,806	2,046	2,087	2,183	2,288	2,391	2,450
Perforation at 2000 yards of Harveyed nickel steel, inches	2.13	3.68	4.85	6.40	10.37	15.04	19.60
Perforation at 2000 yards of Krupp armor .....inches	1.70	2.94	3.88	5.12	8.30	12.03	15.68
Remaining velocity at 3000 yards ..... foot-seconds	1,401	1,690	1,771	1,893	2,068	2,209	2,291
Perforation at 3000 yards of Harveyed nickel steel, inches	1.52	2.85	3.89	5.30	9.06	13.53	17.92
Perforation at 3000 yards of Krupp armor .....inches	1.22	2.28	3.11	4.24	6.61	10.82	14.34

With capped projectiles an increased thickness of from 15 to 20 per cent. may be perforated.

The Maxim, the Driggs-Schroeder, and the Hotchkiss are the smaller rapid-fire guns used in the United States navy to make up the secondary battery of war ships. They range in size from the 1-pounder to the 12-pounder and use fixed ammunition. The 3-pounder semi-automatic gun has a speed of 40 shots per minute and the fully automatic gun a speed of 70 shots per minute. The same device can be applied to and materially increases the speed of the 6-

pounder gun. Maxim has also perfected a fully automatic 9-pounder gun that fires 60 shots in a minute. All these guns have a high velocity and are able to pierce an inch or two of steel at the distance of a mile. They can make a good target at 3000 yards and are a very effective reply to the torpedo boat — "the dread that must be halted when afar." When the 6-pounder guns were tested prior to purchase by the government, the Hotchkiss fired 28 rounds in one minute, 83 rounds in three minutes; the Maxim, 20 rounds in one minute, and 65 rounds in three minutes; the Driggs-Schroeder, 34 rounds in one minute and 83 rounds in three minutes. The honors are supposed to be about even between the Hotchkiss and the Driggs-Schroeder. The latter gun is made by the celebrated firm of Cramp Brothers of Philadelphia. The accuracy of the gun is remarkable. Ten rounds were fired at a target 26 feet by 40 feet, at a distance of a mile, all hitting the target, and the most of them pretty close to the center of impact.

Guns of a yet smaller caliber using the ammunition regularly issued for small arms are called machine guns. Of these the Gatling is the earliest and best known. It was invented in 1861 by Dr. Richard Jordan Gatling. It consists of ten (sometimes five) barrels revolving about a central pivot, something like the cylinder of a revolver, each barrel being fired as it comes opposite a given point. The gunlocks are of the bolt principle and each barrel has its own bolt, firing pin, and cartridge extractor. With the improved Accles feed 1200 rounds per minute can be fired. If an accident occurs to the mechanism of one barrel the other nine can yet be used. The gun is operated by turning a crank and its projectiles have about the same range, velocity, and penetration as the soldier's rifle using the same cartridge. "It can be trained with far more accuracy than small arms from the shoulder. It has no nerves to be disturbed in the din, confusion, and carnage of the battle field." The gun was

perfected in time to be used during the close of the Civil War and gave excellent satisfaction.

In the Franco-German war a few of them repulsed a charge of the best trained soldiers of the German army. In 1898, in the land battles before Santiago, Lieutenant Parker took a battery of Gatling guns to the front, 100 yards in advance of the firing line, and clearly demonstrated that they were equal in firing efficiency to a regiment of soldiers. Having ten barrels the Gatling does not heat as do single barrel guns, and as many as 63,000 cartridges have been fired in a single test without stopping to wipe out the barrels. The gun complete with carriage and limber weighs about 600 pounds, or rather less than a piece of ordinary field artillery.

The Gatling can be used to deliver a high angle fire to trenches. With the gun elevated 85 degrees the bullets describe a curve and descend point downward, striking 500 yards from the gun with a force sufficient to penetrate two or three inches of timber. The gun can be used for this purpose up to its extreme range, the greater the range the less the elevation required. Two Gatling guns with steel shields to protect the operator are furnished each regiment of United States infantry.

The Maxim uses the force of recoil to operate the piece. If a cartridge is put in position and the trigger pressed, the gun continues to shoot as long as the trigger is held back and the ammunition in the magazine lasts. It is claimed that with this gun as many as 700 rounds per minute have been fired. It has but one barrel, which is surrounded by a water jacket to keep it cool. The gun can be made to use the ammunition issued for military rifles.

The Colt automatic is a new machine gun which has recently sprung into notice. It has a thick barrel and does not heat so rapidly from firing as guns with lighter barrels, and the larger surface of the barrel radiates the heat faster and so the barrel has no water

jacket. All that is necessary to operate it after the first shot is to keep the finger pressed on the trigger and the gun aimed, and it will continue to fire at the rate of 400 shots per minute until all the cartridges are exhausted. This gun is not operated by hand as is the Gatling, or by force of the recoil as is the Maxim, but near the muzzle is a small vent from which, when the projectile has reached its

COLT MACHINE GUN.

highest speed, a small portion of the gas is allowed to escape into a gas cylinder fitted with a piston, and from this, motion is transmitted to operate the breech mechanism. Such a system is said to give simpler and stronger mechanism then one employing the recoil to operate it. The gas employed does not decrease the range and accuracy of the gun for it is not used until the projectile has attained its maximum velocity. "The hammer of this gun is also

used as a piston for an air pump which forces a strong jet of air into the chamber and through the barrel, removing all residue or unburned powder after the empty shell is extracted." The United States government tests require for it a speed of at least 400 rounds per minute, but the guns used by the British government are "tuned up" to 500 shots per minute. It is a model of neatness and accuracy. In a recent test, it in one minute placed 185 shots within a 12-inch circle at a distance of 300 yards. Another strong feature is that the gun alone weighs but 40 pounds, with its tripod and mountings complete only 94 pounds, and so can be carried about wherever infantry can go and use the same ammunition as the soldier. "For use in cavalry service, this gun, fitted to a light tripod, can be carried by a trooper in a cavalry boot, the whole equipment being readily transported and handled in action by one man." The gun has given a good account of itself in the Philippines, in South Africa, and in China, its light weight rendering it available where heavier guns could not be carried.

The Evolution of the Modern War Ship.

The application of steam as a motive power to war ships has brought forth some marvelous changes.

The Old vs. the New. The sailing vessel was helpless in a calm. Ships starting from different ports to meet at a given point on a certain day had no assurance they would be able to arrive in time. Their only weapon, the gun, was of so crude a type that it to-day seems insignificant. It had no sights, or only those of the rudest kind, for its range was so short that they were hardly thought necessary. To-day it is fitted with the finest telescopic sights that will show buttons on uniforms miles away. Its round cast iron solid shot would not penetrate the side of a battle ship except at closest range. Modern projectiles will penetrate a yard of wrought iron and each

THE "CONSTITUTION."

THE "OREGON."

TYPICAL BATTLESHIPS OF THE FIRST AND LAST OF THE 19TH CENTURY.

carry a bursting charge sufficient to have wrecked the flagship of Nelson. The torpedo was then a dream of the most sanguine inventor and the ram an impossibility to a ship with sails.

Independence of Steam. Machinery has changed all this. The steam engine has made the war ship practically independent of wind and tide. It can proceed in a straight line continuously and arrive at its destination at a given date, while the sailing vessel went zigzagging with the varying winds and might lie motionless for days becalmed. By machinery huge masses of iron are easily handled that could not have been moved by hand. Rolling mills and steam hammers have made possible the construction of iron ships. As first applied to navigation, steam power could not be used successfully in the battle ship. The huge paddle wheels were easily damaged by shot, and they took up the room on the sides of the ship that should have been occupied by the heaviest guns. With the perfection of the screw propeller and the disappearance of the paddle wheel a new era was inaugurated. Under the most favorable circumstances, the sailing vessel might make fourteen or fifteen knots per hour for a short time. Torpedo boats now make more than forty miles an hour. "Nelson, in his three months' chase after Villeneuve, made an average of 93 miles per day." The United States cruiser *Columbia* steamed from Southampton to New York, over 3000 miles, at an average of more than 500 miles per day.

Nothing Perfect. In spite of the marked progress of the age, the ship builder is constantly reminded that for him there is no such thing as finality, for the triumphs of the gun maker frequently render his ship obsolete almost as soon as it is launched.

"Constitution" vs. "Oregon." It will help us to understand clearly the progress that has been made in war ships if we compare one of the best of one hundred years ago with one of to-day. We will select the *Constitution* and the *Oregon*. Our schoolbooks have

made us familiar with the brilliant war record of the one, and the long voyage around South America and splendid performance at Santiago of the other are still fresh in our memories. The *Constitution* was built wholly of wood; the *Oregon* of iron and steel. The *Constitution* depended for motive power on her vast expanse of snowy sails, stretched on towering masts and tapering yards. In a calm, she was helpless. The masts of the *Oregon* seem like rudimentary organs and she is driven by engines of enormous horse power, making her independent of wind or tide. The one was a picture of grace and beauty; the other is a bare, grim fighting machine.

Dimensions. The *Constitution* was 173 feet long, 44 feet wide, had a displacement of about 1576 tons, a complement of 475 officers and men, and cost $302,718. The *Oregon* is 348 feet long, 69 feet 3 inches wide, has a displacement of 10,288 tons, a complement of 463 officers and men, and cost $6,575,032.76. The *Constitution* was lighted by smoky battle lanterns, inclosing a tallow candle, whose rays penetrated into the darkness but a few yards; beyond that all was gloom. A boat attack by night was a favorite maneuver in those days. The *Oregon* is lighted by electricity and equipped with powerful search lights that can render visible the buildings of a city ten miles away. All the work on the old ship was performed by hand labor; on the new one machinery propels the ship, hoists the anchor, turns the turrets and aims and fires the guns; hand labor is at a minimum. The *Constitution* mounted 54 guns; the *Oregon* has but 16 in her main battery. The weight of all the shot in one broadside of the *Constitution* was 684 pounds.* A single shell from the 13-inch guns of the *Oregon* weighs 1100 pounds. The shot of the *Constitution* would not penetrate the thinnest armor of the *Oregon*. One shot from the 13-inch guns of the *Oregon* develops enough power to lift the *Constitution* bodily more than twenty feet.

* Her shot were short in weight.

Commander's Personal Prowess. A century ago, the commanding officer stood on deck in plain view and encouraged his men by voice and example. In hand-to-hand encounters, even his personal prowess might become a factor. To-day the commander is shut up within a steel conning tower, intended to be impenetrable to shot; only a few officers see him, and his orders are transmitted by means of speaking tubes, telephones, and electric bells.

Range of Guns. The guns of the *Constitution* had an accurate range of less than a mile; the *Oregon*, in pursuit of the *Cristobal Colon* off Santiago, threw 13-inch shells over and beyond the latter ship at a range of more than five miles. The need of armor to defend a ship from such destructive missiles is manifest.

Antiquity of Armor. The idea of armor for ships is an old one. The galleys of the early Greeks and Romans were frequently strengthened by bands of iron which sometimes met at the prow and formed a ram. The Norse "Sea Kings" hung the shields of their soldiers along the sides of their galleys, and later the knights of St. John covered their ships with lead. Of all metals, this would seem the least suitable unless it were for protection against some of the liquid forms of Greek fire. Coming to more modern times, the floating batteries used by the Spanish when besieging Gibraltar, in 1783, were protected by heavy walls of timber, strengthened by thicknesses of hide and bars of iron. The old time line-of-battle ship was, in a sense, armored, for her sides were made heavy and solid about the water line to withstand shot. The 90-gun ship had ribs of 16-inch oak timber, only a few inches apart, covered on the outside with planking eight inches thick and inside seven inches.

The First War Steamer. During the War of 1812 between Great Britain and the United States, Robert Fulton proposed to build an impregnable floating battery, propelled by steam, able to drive away the blockading squadron at the mouth of the Delaware.

Congress authorized the construction of such a vessel. The craft was peculiar enough to be interesting aside from the fact that she was the first steam war ship and larger by tons than any other steamer previously launched. The official report of the government inspector says:—

"She is a structure resting upon two boats, keels separated from end to end by a canal fifteen feet wide and sixty-six feet long. One boat contains the caldrons of copper to prepare her steam. The vast cylinder of iron, with its piston, levers, and wheels, occupies a part of its fellow; the great water wheel revolves in the space between them; the main or gun deck supporting her armament is protected by a bulwark four feet ten inches thick, of solid timber. This is pierced by thirty portholes, to enable as many 32-pounders to fire red hot balls; her upper or spar deck, upon which several thousand men might parade, is encompassed by a bulwark which affords safe quarters. Her machinery is calculated for the addition of an engine which will discharge an immense column of water, which it is intended to throw upon the decks and all through the ports of an enemy. With 100-pounder columbiads, two suspended from each bow, so as to discharge a ball of that size into an enemy's ship ten or twelve feet below the water line, it must be allowed that she has the appearance at least of being the most formidable engine of warfare that human ingenuity has contrived."

Effect of Blockade. The keels were laid in a New York ship yard June 20, 1814, the boat was named *Fulton the First*, and launched October 18, 1814. The low state of the treasury and depression of public credit delayed the completion. Then, too, there were no cannon at New York suitable to arm her and twenty guns had to be dragged by horses over the wretched roads between Philadelphia and New York because of the presence of a blockading fleet at the mouth of the Delaware. In spite of all these difficulties and

the death of Fulton (Feb. 20, 1815) she made her first trial June 1, 1815, nine months after her keel was laid.

"She was found capable of opposing the wind, of stemming the tide, and of being steered among vessels riding at anchor though the weather was boisterous and the water rough. Her performance demonstrated the success of Fulton's idea, and that a floating battery composed of heavy artillery could be moved by steam."

The war having closed, no trial of her fighting qualities was possible. She was used as a receiving ship at Brooklyn navy yard until 1829, when she was blown up.

After the War of 1812 the development of home industries and internal improvements offered such a wide and profitable field to American ingenuity and industry that not much attention was paid to naval affairs. America seemed to be content with the building of wooden frigates similar to those that had distinguished themselves in single combat with vessels of the same rating in the British navy. Correspondingly little was done abroad and for more than a generation the experimental work of a few great engineers constituted nearly the whole sum of naval progress.

Stevens Family of Inventors. The Stevens family stand prominent among those advanced pickets of mechanical progress. For generations they were famous American engineers, and different members of the family were contemporaneous rivals of Fitch, Fulton, Bomford, Ressell, Paixhans, and Ericsson.

Twin Screw Propeller. In 1804 Col. John C. Stevens of Hoboken, N. J., fitted out a steamboat with a double screw. It went from Hoboken to New York and return with an average speed of four miles an hour; for a short distance at the rate of seven or eight miles an hour. His propeller was a crude four-bladed one and his engine was not large enough to develop the power required to make his boat a success. (This engine is now preserved in the

Stevens Institute of Technology at Hoboken.) In 1812 he planned for the defense of New York a circular fort which was to be plated with iron and revolved by machinery, and the same year submitted a plan for a boat closely resembling the now famous *Monitor* type, also to be ironclad. This is said to be the first plan for a fully armored ship. A little later his son, Edwin A. Stevens, who afterward founded the Stevens Institute of Technology, made a series of experiments with 6-pound cannon to determine the resisting power of iron plates.

Stevens Battery. Another son, Robert L. Stevens, designed the Stevens battery in 1832. After a time a government board approved the plan, its construction was authorized, Congress voted an appropriation of $250,000, and its keel was laid in 1843.

As originally planned, it was to be 250 feet long, 28 feet wide, covered with 4½ inches of armor, which the experiments of the Stevens brothers had proved would resist the 64-pound cannon of that day at 30 yards. Triumphs of the gun maker necessitated changes in the vessel from time to time, until her dimensions were nearly doubled, and a square movable turret added, but the gun made such rapid improvement that the craft was unable to keep pace and was never completed, but was broken up and sold in 1881. It was the first ironclad steamer projected, and cost the Stevens family upwards of two million dollars.

Forced Draught. Forced draught was another great improvement made by the Stevens brothers and patented April, 1842. It consists in making all entrances into the fire room air tight, then forcing in air by powerful fans until the pressure becomes all the firemen can endure. By this means air is forced into the furnaces, causing the fires to burn furiously, raising the steam pressure, and making higher speed possible. In the famous chase off Santiago, when the coal passers were falling unconscious in the stifling fire rooms of the

Oregon, the engineer asked the captain to fire a gun that the men might think they were in action, knowing the excitement of battle would make them forget their physical exhaustion.

Ericsson's Propeller. One of the most important improvements in naval engineering was the adaptation of the screw propeller to the war ship, for the screw is small, powerful, simple in construction, not easily injured, and so far beneath the water as to be secure from shot and shell. Rude ones were tried about as early as the paddle wheel, but it remained for John Ericsson to first produce a really serviceable one. His boat, the *Francis B. Ogden*, was given a trial on the Thames river, April, 1837, and attained a speed of ten miles an hour. The Lords of the Admiralty witnessed the trial but did not approve of the scheme.

Its Reception in England. Sir William Symonds, Chief Constructor of the Royal Navy, said: "Even if the propeller had the power of propelling the vessel, it would be found altogether useless in practice because, the power being applied in the stern, it would be absolutely impossible to make the vessel steer."

Ericsson in America. Francis B. Ogden, U. S. consul to Liverpool, and Captain Stockton of the United States navy, induced Ericsson to emigrate to America. A new war ship, the *Princeton*, was authorized, and Ericsson designed her engines, placed them beneath the water line, fitted her with a screw propeller and coupled the shaft directly to the engine. "For the first time in a vessel of war the machinery was placed below the water line, out of reach of shot," and again a marked advance was made. The French at once gave Ericsson's agent an order for a propeller, which they fitted to the war ship *Pomone*, and the British navy changed the plans of the steamer *Rattler*, almost ready to be launched, from the paddle wheel to a propeller of another type.

The Revolving Turret. The period seems to have been a

prolific one for military ideas, and we find Theodore S. Timby, of Dutchess county, New York, presenting in 1841 a model of a metallic revolving tower. He filed his caveat with the patent office January 18, 1843, and the same year completed and exhibited an iron model. A little later he presented a model to the Emperor of China through the American representative, Caleb Cushing. In 1848 a commission of Congress made a favorable report to the Secretary of War upon Timby's proposed system, and when the Civil War broke out he had been granted patents for "a revolving metallic tower" and for a "floating battery to be propelled by steam." His claim was so good a one that when Ericsson began the construction of the *Monitor*, a United States court granted Timby an injunction, restraining Ericsson from proceeding until he should have paid Timby a royalty for the use of his invention. Timby settled with Ericsson and his financial backers, Bushnell and Delameter, for $100,000.

The Lesson of Sinope. An added stimulus was given to invention by the Battle of Sinope, November 30, 1853, where a Turkish fleet, armed with guns firing solid shot and anchored under the protection of a shore battery, was annihilated within an hour by a Russian fleet armed with smooth-bore shell guns. The carnage on the Turkish side was frightful and the loss to the Russians but slight. It was not a battle, it was a massacre. It was after this that Sir John Hay said, "The man who goes into action in a wooden ship is a fool, and the man who sends him there is a villain." The succeeding year the English and French wooden ships were roughly handled by the shore batteries in an attack on Sevastopol.

The long shell gun then loomed up as a most dangerous weapon, and the question of armor for ships received earnest attention. The French, keenly alive to the spirit of the age and mindful of the severe lessons they had received, were the first to actually complete armored floating batteries. In 1854 they constructed and hurried to

the Crimea three floating batteries with a speed of four knots an hour, armed with 50-pound Paixhans guns and protected by four inches of iron. These rendered their best service at the Battle of Kinburn, October 17, 1855, where without material damage to themselves they steamed in close under the guns of the Russian fort and were the chief factor in compelling its surrender.

Era of Ironclad Begins. This was the first appearance in actual warfare of the ironclad and her superiority was proved beyond a question of doubt. "It is with the Crimean War that the age of the ironclad may be said to begin."

First Sea-going Ironclad. The Crimean War over, France at once proceeded to construct an iron-plated frigate. She took *La Gloire*, a wooden two-decker, removed the upper deck and used the weight thus gained to carry a belt of 4½ inch iron armor extending from end to end. She had no ram, but carried the iron plates forward to strengthen her bow. This ship was fitted with sail and steam power, armed with shell guns, could make 13 knots an hour, and was the first sea-going ironclad to be completed. Others soon followed, and so industrious were the French that in 1861 they had a more powerful navy than England.

English Turret Ship. The English did not remain unmoved. In 1859 they produced the *Warrior*, made of iron and especially designed to carry armor. She was 420 feet long, and had a great patch of plate 218 feet long and 4½ inches thick over her battery and water line covering about half her length. In 1860 Captain Coles of the English navy submitted a plan of a ship to carry nine conical turrets, each to contain a pair of guns. The plan was not accepted. The first English turret ship was the *Royal Sovereign*, a three-decker cut down to Captain Coles's plan, plated on the water line and above with 4½ inch iron. Four turrets were placed on her decks protected by armor ten inches in front tapering to five inches

in the rear. The forward turrets carried two guns each and the others each one gun. The turrets were not mounted on a spindle as in the *Monitor* but their bases rested on rollers and the whole was slowly turned by hand power. She was tried July, 1864, and accepted soon afterward. The Coles type of turret is the one in use to-day.

American Civil War. At the breaking out of the Civil War the Federal Government had but one available war ship on the Atlantic coast. The control of the Mississippi river was of the utmost importance, and for this gunboats were necessary. Their need was so urgent that time was of the greatest consideration. Captain James B. Eads of St. Louis, afterward a famous engineer, undertook to construct in sixty-five days seven gunboats, each carrying 2½ inches of armor and propelled by a paddle wheel at the stern fitted into a recess in the hull for the sake of protection. Only a courageous man would have dared undertake such a contract and only one of surpassing executive ability could have carried it out. During a period famous for tremendous exertion and remarkable achievement this mobilization of constructive forces by Captain Eads stands preëminent. "Rolling-mills, machine shops, foundries, forges, and sawmills were all idle. The engines that were to drive this, our first ironclad fleet, were yet to be built. The timber to form the hulls was uncut in the forest; the huge rollers and machinery for making their iron armor were not yet constructed."

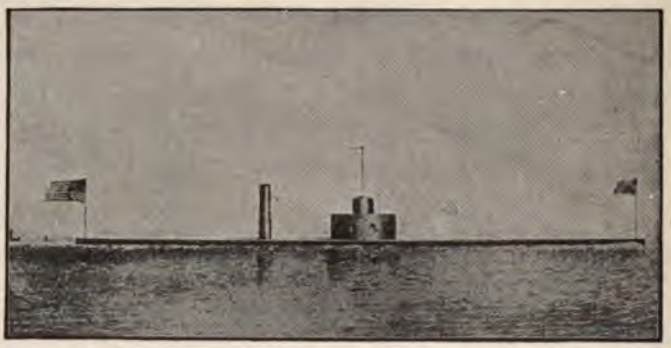
Military Value of Telegraph. "The signatures were scarcely dry upon this important contract before the work was actively begun through telegraphic orders issued from Washington. Special agents were dispatched in every direction, and sawmills were simultaneously occupied in sawing the timber required in Kentucky, Tennessee, Illinois, Indiana, Ohio, Minnesota, and Missouri, and railroads, steamboats, and barges engaged for its immediate transportation. Nearly

all the largest machine shops and foundries in St. Louis, and many small ones, were at once set at work day and night, and the telegraph lines between St. Louis and Pittsburg and Cincinnati were occupied frequently for hours in transmitting instructions to similar establishments in those cities for the construction of the twenty-one steam engines and five and thirty steam boilers that were to propel the fleet. Within two weeks not less than four thousand men were engaged in the various details of their construction. Neither the sanctity of the Sabbath nor the darkness of the night was permitted to interrupt it. On the 12th of October, 1861, the first United States ironclad, with her boilers and engines on board, was launched in the Missouri in forty-five days from the laying of her keel. The others followed in rapid succession. An eighth vessel, larger, more powerful, and superior in every respect, was also undertaken before the hulls of the first seven had fairly assumed shape. In less than one hundred days one individual put in construction and completed eight steamers, capable of steaming nine knots an hour, each heavily armored, fully equipped, and all ready for their armament."

These were the first ironclads the United States used in warfare and in the curved armor deck of Captain Eads we have the prototype of the present protective deck.

Ericsson's "Monitor." Another remarkable feat of naval engineering was shortly to follow. Ericsson's *Monitor* was authorized in 1861. She was especially designed to navigate shallow harbors and rivers and to be impregnable to the fire of forts. She was 173 feet long, 41 feet wide, drew 10 feet of water, and displaced 1255 tons. She had a speed of nine miles an hour, and was protected on the sides by five and on the turret by eight iron plates each one inch in thickness. The rolling mills of the day could not turn out heavier plates. The turret was 20 feet in diameter and 9 feet high and afforded protection to two 11-inch smooth bore guns firing with 15

pounds of powder a 166-pound shot. She was a combination of the Stevens floating battery, the Timby turret, and the Ericsson screw propeller, and cost $275,000. She was completed in 118 days from date of contract and her memorable conflict with the *Virginia* (*Merrimac*) in Hampton Roads, March 9, 1862, was the first battle in the world between ironclad ships.



ERICSSON'S "MONITOR."

"Monitor" vs. "Puritan." While her best directed shots would rattle like hail on the Harveyized steel armor of the *Puritan*, the largest monitor of to-day, a single shell from the powerful 10-inch breech-loading rifles of the latter would crush the flimsy iron plates of the old *Monitor* like an egg shell and bursting inside create frightful havoc. And this is the improvement of but a few decades.

How War Ships are Classified. The boy who asked his father the difference between a battle ship and a cruiser, and was answered that the battle ship was one named after a state and the cruiser one named after a city, may have been satisfied for the moment, but his confidence in his father's infallibility must some time receive a rude shock.

Displacement. One may take up a newspaper and read that the construction of a ship has been authorized of a definite displace-

ment to carry as thick armor and as heavy guns as are practicable. The displacement alone, unless the cost be attached, is usually the only definite quantity named and is now the weight of the ship complete. It is measured by the weight of water she displaces when afloat and is not to be confused with tonnage, which means how much she can carry.

Usually the basis for the designer is the displacement, which may be likened to a bank account, in exchange for which he may have certain things whose total weight must not exceed his proposed displacement. These are the hull, engines, fittings, provisions, coal, stores, ammunition, armor, guns, etc. Their total weight is limited to the displacement, but in what proportion shall he dispose of them? That will depend upon the character of the ship he is to build.

Class Requirements. If a cruiser, to catch unarmed merchantmen, speed is the prime requisite. If a cruiser capable of overcoming other cruisers she is likely to meet, more allowance will be made for armor and guns. If a battle ship, armor and guns will receive the first consideration. If a torpedo boat, to steal unseen upon an adversary in a night attack, the maximum speed and the minimum size will be required. All these types make fairly distinct classes with well marked duties.

Duties of a Cruiser. To harass commerce by capturing unarmed or lightly armed merchantmen and also by creating such terror that merchantmen will not dare put to sea when the cruiser is known to be abroad.

To protect commerce by "convoying" or accompanying as a guard merchant fleets through dangerous parts of a route or from port to port.

To protect commerce by clearing hostile cruisers from the route.

To attack unprotected coasts or those but poorly fortified, or by

their threatening presence compel the enemy to retain ships and men for defense that he would otherwise use in an attack elsewhere.

To carry on small wars at a distance where a powerful fleet is not needed, and to make reprisals.

To act as scouts, to be the "eyes of the fleet." It is important that they have great speed to do this, as after an enemy is sighted every hour of time or fraction thereof that may be given the opposing commander for preparation is valuable.

To keep up communication between a squadron and the base of supplies.

To form the front, rear, and wings of a fleet when in motion, and to be the first to discover the enemy.

To make blockades effective by being able to catch the fastest merchantmen. To be sure, the monitor *Terror* did capture a prize off Havana, but it was because the prize was within range of the monitor's guns when discovered. A hunter doesn't often use a bull dog to catch a fox.

Commerce Destroyer. If the cruiser is to act as a commerce destroyer she must have speed enough to catch the fastest merchantmen afloat and sufficient gun power to overcome them when caught. That she may have speed, the most powerful engines must be given her, and that she may keep at sea for a long time large supplies of coal must be carried, while enough protection must be given to the "vital parts" of the cruiser to defend them from any guns the merchantman is likely to carry.

The parts that must be defended are the engines, the magazines, and the steering gear. Protection is given by placing the "vitals" of the ship below the water line, because few projectiles excepting plunging shot at close range will penetrate much below the water, and by covering them overhead with a steel "protective deck."

Protective Deck. This protective deck, usually extending the

whole length of the ship from side to side, much resembles a huge inverted platter. On the sides and ends it is below the water line, but it slopes or curves upward from the sides, until over the middle part of the ship it is as high, or a little higher, than the water, and presents a flat, or nearly flat, surface, like the bottom of the platter. This deck is made of finely tempered steel, ranging in different ships from one to six inches in thickness. The slopes are thickest and are intended to present an inclined surface from which shot and shell will glance without penetrating. Along the middle part of the ship, between the slopes and the outer wall, bunkers (coal bins) are arranged. These also assist in protection, for a foot of coal is equal to about one inch of wrought iron or half an inch of mild steel for this purpose. Below the protective deck everything may be considered pretty safe from shot and shell. The protected cruiser does not mount heavy guns. If as large as 4-inch or 6-inch they are placed on the highest deck and protected by circular gun shields of steel armor attached to the gun carriage and revolving with it. The shield is usually of face-hardened steel about four inches in thickness, and can successfully resist common shell. If larger than 6-inch guns are carried they are generally placed within a turret.

Along the sides of the ship (broadside) and projecting through portholes are other guns, and the space in front of these is usually protected by light armor.

Having provided for defense against shot and shell, provision must be made against attacks from the ram and the torpedo or accidents to the hull. In cruising on an unknown coast reefs and shoals not down on the chart may be encountered, or in darkness or fog collision with another vessel may occur. In such an emergency the double bottom comes into play. The inner and the outer walls of the hull are from one to three feet apart and the space intervening is divided into numerous little water-tight chambers. Beneath the pro-

tective deck there are several partitions running across the ship (transverse bulkheads) and usually one or more partitions running the whole length of the ship (longitudinal bulkheads). These divide the ship into numerous compartments opening into each other by water-tight doors which can be quickly closed and the ship kept afloat indefinitely with several compartments flooded, if no damage is done to her engines. The *Brooklyn* has one hundred and forty such compartments. The double bottom and water-tight compartments saved the famous *Oregon* when, hurrying to the assistance of those threatened by the Boxers, she struck an unmarked reef on the Chinese coast. A Chinese cruiser whose commanding officer had no sympathy with the Boxer movement came to her assistance and rendered valuable aid. A Russian war ship shortly appeared and the commander intimated to Captain Wilde of the *Oregon* that he should be compelled to seize the Chinese cruiser. Captain Wilde is reported to have said, "Well, I'm a bit embarrassed just now but our guns are in good condition and we've plenty of ammunition." The cruiser remained unmolested.

Inside the armor belt and reaching from the protective deck to above the surface of the water extends a wall (cofferdam) of cellulose. This is frequently made from corn pith and possesses the peculiar property of swelling rapidly when exposed to water, so a shot hole on the water line, if not too large, would be speedily closed by the cellulose.

The engines are such as give the greatest power with the least possible weight, the cost of fuel not counting for so much as in a ship used for purely commercial purposes. So powerful are the engines of a large cruiser that they could drive the machinery to furnish the electric light for five cities of 50,000 inhabitants each. Her enormous coal bunkers hold hundreds of tons of coal that she may make long voyages without being compelled to put into port.

To recapitulate: The protected cruiser is protected against the ram, torpedo, and reef by her double bottom and belt of corn pith; her vitals, liable to injury from shot, are covered by the protective deck and sheltered by the water; her broadside guns are protected by armored casements; her guns on deck by gun shields and light weight turrets. Any of this armor can be penetrated by the heaviest guns of a battle ship, and the commerce destroyer must be able to show a clean pair of heels to anything she cannot whip. Dewey's flagship, the *Olympia*, is a protected cruiser.

The armored cruiser should be able to brush away hostile commerce destroyers and leave the route clear for merchantmen or to act as guardian of them. She is a pretty formidable fighting machine, and might occupy a position in the reserve of a fleet next the fighting line. In her is found high speed and greater displacement, heavier guns, and thicker armor than in the protected cruiser. In addition, she has about her water line a belt of armor probably seven and a half feet wide and from two to twelve inches thick extending above and below the water. This may extend completely around her or along her sides far enough to cover the most vital parts of the ship. It is this side armor that gives her the name "armored cruiser." The ammunition hoists (elevators), passing from the magazines beneath the protective deck up to the turrets, unless inclosed within a tower, are protected by an armored tube from three to ten inches in thickness. The great quantity of coal that her powerful engines require, and other considerations, have hitherto forbidden protecting the space between the turret and protective deck by armor, but the coal is arranged along her sides so as to give some protection, and improvements in the resisting power of armor make it possible each year to give more protection for a given weight. The cofferdam of cellulose, made from corn pith, or some similar substance, is thicker than in the protected cruiser and the hull heavier

and stronger. She has a double bottom like the cruiser of the other class. Some armored cruisers are now made larger than battle ships and mount pretty heavy guns,—in the British navy 9-inch, in the French 9.4-inch, in the German 9.4-inch, in the Spanish 11.2-inch, in the United States 8-inch.

For the purpose of giving a wider arc of fire to guns mounted on the broadside they are frequently placed within bay-windowlike structures called "sponsons." By such an arrangement they can be fired nearly ahead or astern. Guns in the bow of the ship may look out of ports which have been notched, depressed, or cut in to allow the gun to be trained directly ahead. An arrangement somewhat similar is sometimes made for those along the side, to give greater freedom of motion, and ports of this character are said to be "recessed." The heavy guns are placed within the turrets.

The turret is common to the cruiser, the monitor, and the battle ship, and is a circular steel tower with openings called portholes through which guns project. It rests on heavy rollers and is made to turn by machinery so as to point the guns in any desired direction.

The turret was the strongest feature of the original monitor and is desirable because it places the heavy guns over the center of the ship, where they least disturb the balance and can be protected with less weight in armor. A gun in a turret is equal to a gun on either broadside and all economy of weight thus gained can be used to give better armor protection to the ship or more powerful engines giving higher speed. Electricity is the motive power most commonly used to rotate the turrets. Within each turret are usually placed two heavy guns which are moved by machinery and fitted with a peculiarly effective mechanical device for sighting. Between the guns, looking through slits in a projection in the top of the turret (sighting hood), stands the operator who is to aim the guns. In front of

him and looking through two small openings are two cross hair telescopic sights of the best construction. By turning small hand wheels he can move these sights to the right or left, can elevate or depress them, until they bear on the target. As though connected by a chain of sympathetic nerves, the guns, by a peculiar refinement of mechanism, are made to move in the same direction as the telescopes in the sighting hood and when the cross hairs of a telescopic sight cover the vulnerable point in the target the corresponding gun in the turret is properly aimed. Then by means of electricity the gun can be instantly fired. The guns of the *Victory*, Nelson's flagship, were moved with a handspike, sighted by guess, and fired with a match.

Electricity, steam, or hydraulic power supply the force required to move the guns and the machinery of the turret. Since powerful shells exploded underneath the turret would injure the mechanism, it is desirable that something like a gigantic steel tube, or well, with walls of heavy armor, reach from the base of the turret to the protective deck, to protect the machinery and furnish a safe passageway for the ammunition from the magazines below the protective deck underneath the water to the guns above.

The barbette is a steel tower intended to protect the heavy rollers on which the base of the turret rests, the machinery for turning it, the guns within the turret, and all the machinery connected with them. The guns look out over the top of the barbette and, in most battle ships, it extends down to the protective deck. Within this, like a smaller tube within a larger one in a spyglass, is placed the turret, mounted on heavy rollers, with suitable machinery for turning it.

The barbettes show plainly in the pictures of many battle ships, and look like large hoops encircling the turrets at the base. Only the heavy guns of a ship are placed within turrets.

The armored cruiser must have speed sufficient to catch anything but the very fleetest commerce destroyers, and coal endurance sufficient to make long voyages from home. Cruisers have a high freeboard; that is, they stand well out of the water, mounting their guns twenty-five feet or more above the water line, which enables them to be used in rough weather. In this respect they possess a marked advantage over a monitor and a coast defense battle ship, whose guns might sometimes be almost under water, or their muzzles so far depressed that, if fired, their projectiles would strike the tops of the waves between them and their target. On this account a naval officer has said, "In a high sea the *Brooklyn* [armored cruiser] could knock seven bells out of the *Oregon* [battle ship]."

The Conning Tower. Back of the forward turret, and high enough above the deck to give a good view over all, is the "conning tower," an armored steel-tower, pierced by narrow slits through which the commanding officer watches the progress of the battle and directs the movements of his vessel. This tower contains the battle steering wheel and is connected by electric bells, speaking tubes, and telephones with every portion of the ship with which the captain will need to communicate. The conning tower should be strong enough to resist the ordinary fire to which it is likely to be subjected, and the electric wires communicating with it are, to protect them from shot, usually run through an armored tube until they pass beneath the protective deck. Above the conning tower is usually found a rather frail structure, not built to resist shot and shell, called the "chart house," from which the ship is navigated, except in battle.

Military Masts. Cruisers of this class carry what are known as "military masts." These are not intended for the use of sails, but are hollow, tapering steel structures, about which are built one or more platforms or balconies, where riflemen and machine guns are

placed. The fire from these is expected to sweep off the men from the exposed positions of the hostile ships. Cruisers are also furnished with powerful electric search lights, frequently of 100,000 candle power or more, which can be turned so as to throw their rays in any direction and render visible objects miles away. The electric search light and the small rapid-firing gun are the war ship's defense against her small but terrible enemy, the torpedo boat.

The armored cruiser is not expected to engage the battle ship unless the conditions are such as to give her some advantage to make up for her lighter guns and thinner armor. If the battle ship were injured so that she could not fire all her guns, or if water had entered some of her compartments and thrown her off an even keel, so but few of her guns could be pointed in some particular direction, the cruiser might by reason of her superior speed take this position and remain where, without great damage to herself, she could pour in a destructive fire upon the disabled battle ship. In general the cruiser trusts to her speed to keep away from anything she cannot whip. The *Brooklyn* and the *New York* are good types of the armored cruiser.

The battle ship built to fight and not to run carries the most powerful guns and the best armor consistent with her displacement and seagoing requirements. The battle ship is usually larger than the armored cruiser, the hull is stronger and perhaps has a triple bottom divided into numerous water-tight chambers reaching up to and forming a shelf on which her armor belt rests. She has a heavy protective deck, an armor belt from seven to eight feet in width and from eight to eighteen inches in thickness. Above the protective deck transverse armored bulkheads (partitions) are built fore and aft to stop the enemy's shells, which might come in at the stern and bow. Along the sides, above the armor belt connecting the bulkheads, sufficient armor is placed to keep out medium gun fire; that is, common shells and projectiles from guns six inches and smaller.

Since this armor must be so heavy (perhaps one third of the entire displacement of the ship is given to it), it is impossible to completely cover the ship with it, and so we find it in the form of a huge steel box (redoubt) extending far enough ahead and astern to include within its walls the machinery moving the turrets, the ammunition hoists, and the most important parts of the ship above the armored deck. It is expected that considerable portions of the bow and stern above the protective deck may and probably will be shot away in action, but this might be done without much damage or loss of life and the battle ship still be able to maintain a most formidable resistance. The destruction of the unarmored bow might impede the speed of the ship and cause her to steer badly, and water coming in here or at the stern might put the battle ship on an uneven keel, perhaps to such an extent that she would be troubled to bring her guns to bear on an enemy. In such positions she would present an inviting target for the attack of the torpedo boat or the ram.

The batteries of our battle ships are known as primary and secondary. In the primary battery are the large guns from 8-inch to 13-inch, with which she will attack the thick armor over the vitals of her opponents and the opposing heavy guns. The primary battery must be supplemented by smaller rapid-fire guns from 4-inch to 8-inch and with these she will attack the unarmored or thinly armored portions of the opposing ship and the portholes through which the heavy guns look out.

The secondary battery is made up of smaller rapid-fire guns, such as Maxim, Nordenfeldt, Hotchkiss, Driggs-Schroeder, Colt, or Gatling, whose projectiles range in size from that of a rifle ball up to a 12-pounder, and fire from 30 shots a minute for the former to 400 or 1200 shots a minute for the small machine guns. With these she sweeps away men from the exposed positions on the hostile deck and defends herself when attacked by the torpedo boat.

The battle ship of to-day represents a compromise of conflicting requirements. Since the advent of horizontal shell fire, there has been a continuous struggle between the shipbuilder and the gun maker until the modern battle ship is a huge floating mass of complicated machinery. Besides the engines used to propel her she may have a hundred others. Separate engines steer the ship, hoist the boats, raise the anchors, turn the dynamos, pump water, compress air, furnish power for the machine shop, hoist ammunition, move guns, turn turrets, ventilate the ship, and even distill water for the use of the engines and crew, for drinking water is no longer carried in water casks; in a word engines do what was formerly done by hand labor and do it better. It is no longer sufficient for the commanding officer to be merely a good sailor and a stout fighter. Brains and technical training of a high order are necessary to command this intricate mass of machinery, containing more than a mile of steel tubing, with boilers giving an acre of heating surface. The ship, if used as a ram, could strike a blow that would lift 200,000 tons a foot high. The skill required has dignified subordinate positions until we find warrant machinists paid $1200 per year, and chief gunners, chief carpenters, chief boatswains as high as $1960 per year. Small wonder that the battle ship has the confidence of her designers.

The "Monitor," a boat of peculiar construction built by John Ericsson, has come to designate a type. The type characteristics are the turrets mounting heavy guns, low sides (free board), thick armor, low speed, and light draft. The spectacular appearance of the first *Monitor* at a critical moment seems to have given the type a higher value in the eyes of most Americans than its abilities justify. It is a most useful vessel within its sphere, but that sphere is limited. As harbor defense boats they can render excellent service. Secretary Long has said, "There is no advantage to be gained by building ships of this description. Such a vessel cannot attain to high

speed. It can neither overtake nor escape from a battle ship. Its comparative smallness of target, usually mentioned as one of its chief advantages, is apparent rather than real, for that feature of the battle ship which changes the size of the target, although vulnerable, is not indispensable to the safety or fighting efficiency of the vessel. The chief defect to be found is the serious disadvantage under which its guns are fought in any but the smoothest water."

Originally, the monitors were planned to carry only heavy guns, but the appearance of the torpedo boat compelled the building of a superstructure to carry search lights and rapid-fire guns. Of course guns in this position are as much exposed on the monitor as on any type of ship.

The Idea of Submarine Attack is not New. In the War of the Revolution a submarine boat attacked a British man-of-war in New York harbor, and in the War of 1812 Robert Fulton devised and advocated the use of the spar torpedo which a half century later men like Lieutenant Cushing used with terrible effect.

In the Civil War the Torpedo Boat Played a Prominent Part. It appeared as a small boat with a spar in the bow to which was attached a torpedo to be exploded on contact. One of the most successful attacks was on the United States ship *Minnesota*. A small launch fitted with a long spar at her bow, to which was attached the torpedo arranged to explode upon contact, steamed, in the darkness of night, through the blockading fleet without its identity being discovered, although frequently challenged by lookouts. The *Minnesota* was found, the torpedo was lowered, the spar run out, and a dash made for her side. Although the torpedo was loaded only with gunpowder, the explosion was terrific, and resulted in such severe damage to the *Minnesota* that she was compelled to be docked. The torpedo boat escaped in safety.

It was in a simillar boat and with a spar torpedo, that Lieutenant

H. M. Torpedo Boat Destroyer "Daring." Speed, 27 Knots per Hour.

Cushing, of the United States navy, made his successful attack upon the Confederate ironclad *Albemarle*. In the absence of the search light and the small rapid-fire gun, such boats in the hands of fearless men were a dreaded and dangerous enemy on dark foggy nights.

Late in the sixties the Whitehead torpedo was introduced and special boats designed and armed with it. They were made small, for the safety of the boat depended upon not being discovered. Heavy guns cannot be moved quickly and the gun maker replied to the torpedo boat's challenge with the small rapid-fire gun and the machine gun, the powder maker contributed smokeless powder, and the electrician produced the search light. Under favorable circumstances the torpedo has an effective range up to 800 yards, and the boat must get at least that close before being discovered and destroyed. Once discovered she will be exposed to a veritable shower of small projectiles. Her existence depends on making this exposure as short as possible, and everything has been sacrificed to extreme speed until the boat is a mere steel shell driven by engines on which the best machinists have exhausted their ingenuity. To obtain speed the size has been increased until the very object for which it was originally intended may have been defeated. The high speed at which they move throws up a bow wave that is visible even in a dark night. English boats driven by the Parsons steam turbine have made more than forty miles an hour.

The Torpedo Boat Destroyer, as its name suggests, is a larger boat, built to afford protection against hostile torpedo boats. There is much difference of opinion as to the merit of torpedo attack. No vessel has yet, when in motion at sea, been destroyed by the torpedo and torpedo boats can do little against the battle ship whose secondary battery is in good shape. The torpedo boat's time in battle will come toward the close of the action, when the ships are partially disabled, the crews tired, and the rapid-fire battery dismounted or

silenced; then, after a ship is disabled, perhaps on uneven keel, she will fall an easy prey to the torpedo boat.

The Torpedo Boat has a very real Influence upon Naval Warfare. The knowledge that a harbor is defended by such a fleet and the danger that the floating batteries costing millions of dollars will be destroyed by the insignificant yet terrible little enemy will make an attacking squadron cautious. The constant strain upon the nerves in keeping a lookout and the very fear that torpedo boats incite well repay their construction, should they render no further service.

"She's a floating boiler crammed with fire and steam,
A dainty toy, with works just like a watch;
A weaving, working basketful of tricks —
A pent volcano stoppered at top notch.
She is Death and swift Destruction in a case
(Not the Unseen, but the Awful — plain in sight).
The Dread that must be halted when afar;
She's a concentrated, fragile form of Might;
She's a daring, vicious thing
With a rending deadly sting —
And she asks no odds nor quarter in the fight!"

Automobile Torpedoes. The rapid-fire gun and later the development of the electric search light and smokeless powder rendered the spar obsolete and inventive talent turned itself to producing a torpedo that could be used at longer range.

The Whitehead, the one now most generally used, appeared in crude form in 1868. As perfected it is a long fish-shaped shell having three compartments. The first chamber, called the warhead, is detachable and contains the explosive charge and the means of exploding it. The warhead is kept in the ammunition magazine and attached to the torpedo only when ready for action. Wet gun cotton is the explosive usually chosen because it is more powerful than most and one of the safest. The wet gun cotton in a warhead has been known to be struck in action by a shell without exploding. It

is exploded by the detonation of another explosive, a fulminate of mercury primer igniting a small quantity of dry gun cotton being the means usually employed. The second chamber contains the compressed air cylinder, which furnishes the motive power to turn the propeller, and the third chamber the machinery for turning the screw propeller at the stern. Modern torpedoes are from 14 inches to 18 inches in diameter, from 11 feet to 18 feet long, are charged with 120 pounds to 220 pounds of wet gun cotton, and can run about 800 yards, the greater part of the distance at a 30-knot rate. A torpedo is thrown from a torpedo tube by a light charge of gunpowder, and the machinery within it being set in motion it at once begins to propel itself, hence the name automobile. Much skill is required in the use of the torpedo. If fired at a target which is in motion allowance must be made for the changed position of the target by the time the torpedo reaches it and the "acquired motion" of the boat from which the torpedo is fired must be considered. The modern torpedo is an intricate piece of machinery and costs complete about $3100.

The Howell torpedo is the invention of an American and differs from the Whitehead chiefly in having within it a heavy balance wheel in place of the compressed air motor. Before launching, the wheel is spun up to a high speed and its momentum is employed to drive the torpedo's screw propeller.

Submarine boats, or the plans for them, first appeared about 400 years ago. William Bourne of England in 1604 designed one which was never built. A German, Cornelius Van Drebbel, tried one on the Thames in 1624 in the presence of King James I. The boat was moved by oars passing through the sides, the openings being made water-tight by leather stuffing boxes. It is said that the boat could be completely submerged and the air "kept pure by means of liquids." During the next hundred years a few attempts were made,

but these resulted frequently in the loss of life of the inventor. The first American submarine boat dates back to the time of David Bushnell of Saybrook, Connecticut, who in 1775 designed and made a turtle-shaped cask about 7½ feet in diameter, large enough to contain a man and air to sustain him for 30 minutes. The boat was entered by a water-tight trap door at the top and carried a heavy lead weight at the bottom which could be detached by the operator and allow the boat to come to the surface quickly. It was steered by a small rudder and propelled by a screw propeller turned by hand. This was apparently the first appearance of the screw propeller in navigation. Its course was directed by a compass, and a water gauge showed the depth of submersion. A bottle containing phosphorus furnished the light by which to read the compass and water gauge. Water was admitted into compartments to sink the cask to the required depth and expelled by two force pumps. The torpedo consisted of a cask containing the clockwork and 150 pounds of gunpowder attached by a short rope to a wood screw which was to be screwed into the hull of the ship to be destroyed. In this boat an officer named Lee in 1776 made an attack on a British 50-gun ship near Governor's Island in New York harbor, but the wood screw striking a bolt in the hull it failed to fix the torpedo. The operator was forced to come to the surface and abandon his torpedo, which later exploded, causing little damage but much alarm. In 1801 Robert Fulton designed and operated in Brest harbor, France, a submarine boat in which he remained submerged for one hour. In 1814 he suggested the form of spar torpedo which was used in the American Civil War. That contest brought out the famous Confederate "cigar boat," the immediate prototype of the *Holland*. She was propelled by machinery, driven by hand, and caused to dive or ascend by means of horizontal rudders on her sides. Although in her experiments she sank four times, each time with the loss of her

entire crew, it was never difficult to find adventurous spirits to man her. The fifth and last experiment resulted in the sinking of the United States war ship *Housatonic*. The "cigar boat" also disappeared and with her the greater part of her crew.

In 1886 Nordenfeldt brought forward in Stockholm a boat driven by steam power which could dive for five minutes at a time. Lieutenant Peral of the Spanish navy in 1888 presented for trial a boat named after him. Storage batteries furnished the motive power. France later produced submarine boats, but all of these lose their sense of direction when the course is changed under water and are compelled to come to the surface to get new bearings.

Experiments with submarine boats having by 1887 attracted considerable attention, the United States navy issued a circular calling for plans of a submarine boat that would show a speed of fifteen knots on the surface, eight knots when submerged, and capable of running thirty hours on the surface and two hours submerged. The boat was required to turn within four times her length and to sink in thirty seconds. Several boats were presented for trial in response to the circular.

It remained for John P. Holland, an American inventor, to design the first satisfactorily working submarine boat. It (the *Holland*) is 55 feet long, 10¼ feet in width, and displaces 75 tons. The hull is cigar-shaped and made of steel. It is double, with numerous compartments in which are stored gasoline for fuel, and others, called trimming tanks, into which water can be admitted through valves. The water is used as ballast and can be blown out by compressed air. When moving on the surface the power is furnished by a gasoline engine; when submerged, by storage batteries. The engine and the dynamo are each attached to a common shaft operating a screw propeller. Storage batteries weighing 21 tons are located near the middle of the ship well toward the keel and so far below the center

THE "HOLLAND" CRUISING.

DIVING.

JUST DISAPPEARING.

COMING UP.

of buoyancy that they aid in keeping her right side up. With all her crew and stores aboard the boat has only her turret and about 18 inches of the hull above the water. She then has an excess of buoyancy of about 250 pounds and water is admitted or blown out of her trimming tanks to keep her buoyancy at this point. In this condition the influence of her horizontal rudders will cause her to dive or to ascend. If when submerged an accident should occur to her propelling machinery she would rise to the surface.

The gasoline engine has 45 horse power and the storage tanks hold five tons of gasoline for fuel. The engine can run the dynamo and charge the storage battery in eight or ten hours, and the battery will furnish 50 horse power for six hours, enough to enable the boat to run submerged about fifty miles. The boat contains air pumps

for supplying compressed air for machinery, guns, and crew. When submerged she uses the exhaust from the steering engines to keep good the atmosphere breathed by the crew. In her bow is a submerged torpedo tube from which can be thrown the regular 18-inch Whitehead torpedo (see Whitehead torpedo in text). She carries in addition two pneumatic guns; one forward, one astern. The one astern will propel under water with an energy of 750 tons a shell containing 100 pounds of dynamite. The gun forward can fire similar shells through the air and has a range of 1800 yards. To use the forward gun the boat would need to go to the surface but remain only an instant, for the recoil from the gun when fired would force the boat under water and out of reach of the enemy's projectiles. The pneumatic guns have a bore of 8⅝ inches and can be fired by powder and air, or air alone may be used. One pilot, one electrician, one engineer, and two torpedo experts form the crew. She has a telescopic turret that can be projected three feet above the water in a second or two, or, remaining wholly under water, a tube can be thrust up containing a camera obscura which will reflect upon a white sheet of paper in the turret a picture of the harbor or sea for miles.

Several trials were given the *Holland* and although at the first she showed considerable merit, yet it was not until November 9, 1899, that the board reported "every requirement fulfilled," and said, "The *Holland* is a successful and veritable submarine torpedo boat, capable of making a veritable attack upon an enemy unseen and undetectable." There is no reason to consider the submarine boat as unsafe. Indeed, in war it has many more chances than a torpedo boat and it can be made almost absolutely safe. Its crowning virtue is that it makes blockading almost impossible. In the maneuvers of the American squadron off Newport, she showed that she possesses about all the good qualities ever claimed for her.

In view of the successful performances of the *Hollaud*, it is inter-

esting to read that a European of high authority said in 1898, "The Americans, in attempting to solve at one blow all the problems involved in a submarine torpedo boat, have accumulated too many difficulties."

As a harbor defense boat, the fear she would inspire in a blockading squadron would alone be worth a whole fleet of monitors. After viewing her successful performances a naval officer declared that she had shown "the worse than worthlessness of the present above water torpedo system, its methods, theories, and appliances, the need of a deliverance from its absurdities and from the fool's paradise of its false security."

"She is the only kind of an inexpensive draft that can move up to a battle ship in daylight in the face of her fire and in spite of her force of defenders and force the ship to move off or receive a torpedo. An inexpensive boat with a crew of five that can within a limited field prevent operations attempted by an expensive battle ship with a crew of some hundreds surely has a tactical place in naval warfare." An officer says of her, "When a shot or two through her stack intimated that the enemy were getting her range, she would out fires, douse stack, seal up, head so as to intercept the ship's course, dive, and make a run at five fathoms below the surface of about 500 yards, and then rise till the top of her turret or that of her camera-lucida tube above water gave a view of the enemy. Gun fire would be employed against her, but the chances of its proving effective are hardly worth considering, when it is remembered that she would present as a target only a few square inches of armored turret or the top of her camera-lucida tube for a few seconds at a time, in unexpected and impossible-to-predict places. The small chance of disaster due to gun fire would certainly not be enough to deter, when escaping, it would mean the defeat of 500 men in an expensive battle ship by five men in an inexpensive boat. When the boat arrived within 300

yards of the ship, she would make her final dive, deliver her bow torpedo from her axial tube, pass under the ship if her direction were good enough — and at such close quarters she could hardly miss — and as the light through the water gave notice that the ship were passed, the stern torpedo would be delivered against the ship's hull. The attack could always be avoided by the ship's steaming away at speed, for the boat could not chase submerged for any length of time faster than eight or nine knots, though she could make short runs at twelve; but if the boat chased the ship away she could be considered to have given a good account of herself."

Gunpowder. The claims of Roger Bacon, 1267, and Bartholdus Schwartz, 1320, to the invention of gunpowder, are not considered well founded. The origin of gunpowder is lost in the mists of antiquity, but a prevailing belief seems to ascribe its birthplace to Southern China or Northern India, where saltpeter is found in large quantities. The Chinese used it to propel rockets two thousand years ago. The exact formula, saltpeter 75, charcoal 15, sulphur 10, was known to the Arab chemists of the eighth century.

The action of gunpowder is based on the well known laws of combustion, the usual manifestations of which are heat, light, and gas. A piece of wood will burn more rapidly if reduced to shavings, because oxygen, which constitutes about one fifth of the atmosphere, is necessary to combustion, and more of it is brought into contact with the shavings than if the wood be solid. An *explosion* is a rapid combustion; a *detonation* is a rapid explosion. The phenomena of an explosion, like a combustion, are heat, light, and gas. Heat applied to water converts it into steam, causing it to occupy 1700 times its former space. Man utilizes this law and calls the result power. The heat in an explosion acts upon the particles of gas in the same way as in steam causing them to occupy still more space. An explosive is a substance or a mixture of substances which when heated,

struck, or subjected to the shock of an explosion results in the extremely rapid formation of great quantities of highly heated gases. That explosive is the most powerful which will produce the greatest volume of gas at the highest temperature in the shortest time. The definitions of *mixture* and *compound* are familiar.

Mixture and Compound. The ingredients of explosive *mixtures* are mixed mechanically and may be separated by mechanical means. Black powder is a *mixture*. The ingredients of explosive *compounds* are united chemically and can be separated only by chemical means. Smokeless powder is a *compound*. Black powder is made by mechanically mixing in the proper proportions saltpeter, sulphur, and charcoal. With every explosive it is necessary to have something to burn (a combustible) and something to feed the flame with great quantities of oxygen (an oxidizer). The charcoal is the combustible and the saltpeter the oxidizer. The sulphur makes the mixture burn at a lower temperature. The proportions of the ingredients vary with the purpose for which the powder is to be used. These are separately pulverized, carefully weighed, and then placed within a gun-metal or copper barrel (drum) having an axle with arms. The barrel is turned in one direction and the arms revolve in the other. The charge is thoroughly mixed for five minutes. It is next slightly moistened with water and ground under heavy rollers. This is called "milling" and the product called "mill cake." It is done to bring all the ingredients into the closest possible union with each other. Water is put in to prevent dust, to aid the mixing, and to reduce the effects of a possible explosion. The mill cake is then made into powder meal by being passed through two pairs of toothed rollers. The powder meal is then placed in a press box, where it is made into hard slabs called "press cake."

Processes. Milling and pressing are the most important processes, for to burn quickly the ingredients must be thoroughly mixed and

brought together as closely as possible. To burn uniformly it must have a uniform density, and milling and pressing bring the particles into closer union and regulate the density. Unless it burns uniformly it will not shoot accurately. The press cake is then placed in the granulating machine, consisting of toothed rollers of varying size which break it into grains of the size required. The powder is next passed through revolving reels covered with canvas cloth, where the dust is removed. It is then ready for glazing, which is done by placing 100 pounds of powder with ½ ounce of graphite in an oaken barrel and revolving rapidly for six hours. This gives it a high gloss and makes it less likely to absorb moisture from the air.

Good black powder should be hard, of a uniform color without any specks of saltpeter or sulphur, free from dust, and should not soil the hands. The size of the grains of powder depends upon the caliber of the gun in which it is to be used, varying from the finest grains for small pistols, to grains an inch or more in diameter for heavy cannon. With ordinary cannon powder it has been found that seven eighths of the entire charge is consumed before the shot passes over one third the length of the bore. This action causes excessive pressure at or near the breech of the gun and very little at the muzzle. For the purpose of reducing the initial strain and getting a more progressive pressure, cannon powder is pressed into grains of varying shapes; a six-sided figure with holes through the mass seems to give the best results.

Brown powder, also called from its color "cocoa powder," is a variation from black powder, consisting in general of a mixture of about 80 parts saltpeter, 15 parts of wood, not wholly charred, and a little sulphur, and sometimes about 4 per cent. of sugar is included. Brown powder proved superior to black powder for guns of large caliber; which superiority was supposed to be due to the fact that the charred wood contained more oxygen than the charcoal, and so pro-

duced a greater volume of powder gas, aided by the carbon, hydrogen, and oxygen present in the sugar.

Such is black or brown gunpowder, and with comparatively slight changes it has fought the battles of centuries. Used in the musket of one hundred years ago it gave the soldier a hard "kick," threw the bullet only a moderate distance, and that in a curve that differed greatly from a straight line. Its materials were not all converted into gas, a large portion being left to foul his gun and render his shooting inaccurate, while the puff of black smoke revealed his position to the enemy. Batteries in action have been enveloped in such dense smoke that they have been captured by the bayonet charge of the enemy approaching unseen. Some things may be said in its favor. Its behavior is pretty uniform and its shooting on this account accurate. Its gases also are not very destructive to the bore of the gun.

The cannon charge of black powder was bulky, weighing one half as much as the projectile. Seeking to find a substitute that should occupy less space in the powder chamber and yet give the required velocity, the chemist eliminated nearly all those parts of the charge not actually used, and converted the remainder almost wholly into gas. He fairly stumbled upon *smokelessness* and barely recognized then the feature that is now a much desired object. The gain was evident. The new charge weighed less, it took up less space in the cannon, permitted the saving of weight at the breech, where the gun was heaviest, for instead of giving a sudden blow to the projectile, as did black powder, it pushed it not only the whole length of the gun but even after it had left the muzzle. The metal saved at the breech of the cannon was added to the muzzle and gave a taper glistening tube one third longer, throwing its projectile with less strain, faster, farther, in a flatter curve, with more energy and greater penetration. The smokeless feature gave the gunner a bet-

ter chance to aim and the torpedo boat can no longer steal up covered by the smoke of battle.

Smokeless Powder. "As to the use of smokeless powder in the Springfield .45 caliber rifle the fact is known that its pressures run very high in small arms, frequently exceeding 40,000 pounds per square inch in our army magazine rifle. It is only by dint of supreme effort, and after years of careful and exhaustive experiments, that a smokeless powder has at last been found suitable for the .45 caliber Springfield rifle; one which may not overtax a breech mechanism calculated originally to resist a pressure of not more than 24,000 pounds per square inch. An increase of the black powder charge (70 grains) now used, by about 10 grains, will exceed the safety limit in the Springfield, although the pressure due to the use of black powder in this arm is moderate and uniform. We use this word "uniform" advisedly, as it is a well established fact that the pressure due to the use of smokeless powder in small arm rifles under certain and not very abnormal circumstances, are quite variable; in fact, we may say that at times they are treacherously inconsistent, and demand an exceedingly stable and positively resisting breech block, something akin to that of the Sharps rifle or bolt system."

Smokeless powder has come to stay, but there is yet room for improvement. Its susceptibility to extremes of heat and cold affects the accuracy of its shooting. It sometimes behaves in the most bewildering manner. The service charge has been known to give a pressure of 70,000 pounds in the .236 navy rifle. If in response to the frantic howls of some newspapers such powder had been issued to the volunteers of the Spanish war there would have been more American soldiers killed by bursting guns than by Spanish bullets. Beginning with 1892 Congress was asked every year for an appropriation for small caliber guns and smokeless powder but it turned a deaf

ear and the appropriations were so inadequate that the magazine guns were supplied only to the regular army and the smokeless powder cartridges available for practice averaged two per man per day and left none in reserve. The country had been warned of this plight by the chief of ordnance as far back as 1893.

Most smokeless powders are made from preparations of gun cotton or nitroglycerin, explosives that are so sudden and violent in their action that it is necessary to mix them with a "restrainer" to retard combustion.

Smokeless powder injures the gun in two ways: by *wash* and by *erosion*. *Wash* is the cutting away of the gun by columns of gas at a high temperature and under heavy pressure escaping rapidly past the side of the projectile. *Erosion* is the eating of the surface of the gun by the particles of gas moving rapidly at a high temperature under great pressure. Erosion takes place chiefly a short distance in front of the powder chamber, not in the powder chamber, where it is not in motion, nor at the muzzle, where the temperature is reduced. Wash occurs at any point in the gun where the gas can get past the projectile.

Cordite, the smokeless powder used by England, consists of nitroglycerin 58, gun cotton 37, vaseline 5. It is highly destructive of the bore of the gun but is not so markedly injurious to small calibers. A high English authority says, "Our heavy guns wear so intolerably fast that we cannot reckon on the velocities we assign to them for any considerable number of rounds." England at least has more trouble in this respect than other nations acknowledge. She alone uses cordite. The smokeless powder used by Germany contains about 25 per cent. nitroglycerin.

A new smokeless powder of the pyro-cellulose type used by the United States navy seems to give excellent results and to be somewhat in advance of that of any other nation. Extremes of

heat, cold, and moisture seem to affect it but little, and the department reports that it gives low pressure and high velocity, while thus far erosion is almost an unknown quantity. As a comparison, where the old style brown powder gave a velocity of 2000 feet with 15 tons pressure, the new powder with but little more pressure gives a velocity of 3000 feet, thus throwing its projectile farther, faster, in a flatter curve, and with greater energy and penetration. This powder has worked so well that the service velocity has been raised from 2000 feet per second to 2800 feet for the heavy guns and 3000 feet per second for the cannon of smaller calibers. A 4-inch gun was fired 661 times and a 5-inch gun 666 times with this powder without causing enough wear to be detected by the most delicate gauges in use at the proving grounds, a remarkable gain over the performances of any other powder. Its good qualities are attributed to its producing an unusually large volume of gas at a much lower temperature.

Lyddite, used by the English as a bursting charge for shells in their South African war, is practically identical with melenite, which the French* used as a bursting charge. They are both made from soluble gun cotton dissolved in ether and acted upon by picric acid. Until recently they have not been regarded as very stable. Armor-piercing shells loaded with jovite as a bursting charge have been fired through four inches of hardened armor and exploded in the rear of the plate, showing that such projectiles could be fired through the side of a ship and exploded within, where their destructive effect can be easily imagined.

Powder in small grains burns so quickly that large cannon cannot withstand the resulting shock. This feature brought the making of large guns to a standstill until General Rodman, the eminent artillerist, discovered that by making the grains larger, pressing the pow-

*The first successful smokeless powder was developed in France.

der harder, and perforating it, he could control its combustion, for as a piece of powder grows smaller in burning it has less burning surface and generates less gas. Rodman, by perforating large powder grains and firing them from the inside, made the burning surface increase as the powder was consumed and constantly increased the volume of gas generated. The same principle is used to-day with smokeless powder.

Gun cotton was first manufactured by Schonbein in 1845 but proved dangerous to handle until rendered safe by purifying, pulping, and compressing it. It is made by steeping pure dry cotton in a mixture of the purest and strongest nitric and sulphuric acids. Waste from the spinning rooms of cotton mills is usually employed. This is thoroughly cleansed and dried. Sulphuric and nitric acid in the proportion of three to one are mixed and allowed to cool. One part of cotton is then immersed in ten parts of the mixture for ten minutes. The cotton is removed, nearly all of the acid squeezed out, and the cotton put in an earthenware crock for twenty-four hours to "digest." It is then removed, washed, and wrung out, afterward reduced to pulp, when it is again washed in fresh water and then in water containing lime, caustic soda, and marble dust to neutralize any acid that might remain. It is then molded into little rectangular blocks each with the corners cut off and a hole made through its center. Gun cotton before being made into pulp differs but little from ordinary cotton. It is harsher to the touch and less flexible. The blocks are saturated with water and packed in the torpedo cases. Containing 30 per cent. of water they can be exploded only by the detonation of dry gun cotton placed in contact with them. To develop the force of gun cotton it must be strongly confined and unless so confined is not very sensitive to shock. Cold has little effect on it. It explodes at a temperature of 360° Fahrenheit. Compressed gun cotton in small quantities may be safely lighted in the hand,

placed on the ground, and the flame extinguished by pouring water on it.

Liquid Air as an Explosive. Those engaged in exploiting liquid air have urged the use of that article as an explosive, claiming for it a pressure of 12,000 pounds per square inch, but a cubic foot of gun cotton can be detonated in 1-2000 part of a second and the mass converted into gas which before it expands exerts a pressure of more than 800,000 pounds per square inch. Although one of the most powerful explosives it is the safest known.

Nitroglycerin was discovered in 1847 by A. Sobrero. Cotton and pure glycerin are chemically about the same, and nitroglycerin is made from glycerin as gun cotton is made from cotton, by mixing pure glycerin with the purest and strongest nitric and sulphuric acids. Any fatty impurities in the glycerin used make the compound unstable and are a fertile source of accident. Nitroglycerin is made by mixing about 600 pounds of nitric acid with about 1100 pounds of sulphuric acid in a leaden tank and letting it cool for twelve hours. This is then run into a cast iron tank surrounded by a larger tank filled with water. Within the smaller tank are spiral pipes through which cold water circulates to keep down the temperature. Two hundred and forty pounds of glycerin in the form of spray is then mixed with the acids. This is a dangerous proceeding; considerable heat is evolved, the temperature must be watched, and if it goes above 80° Fahrenheit the operation is suspended. After the charge has been mixed it is allowed to remain for a few minutes. The nitroglycerin soon forms, rises to the surface, and is separated from the acid mixture. The nitroglycerin is then washed with fresh water and afterward with a solution of carbonate of soda until all traces of the acids are removed and the compound shows an alkaline reaction. Freshly made by the Mowbray process it is a creamy white, opaque, oily liquid, but after standing it "clears" and becomes

transparent and colorless or nearly so. As found in commerce it is yellow or brownish yellow. It does not mix with and is not affected by cold water. It has a sweet, pungent, aromatic taste and is an active poison. The fumes from it produce violent headaches.

Pure nitroglycerin is not sensitive to friction or moderate percussion except when pinched between metallic surfaces. When confined and struck a smart blow it explodes on account of its incompressibility. When in a state of decomposition, however, it may be extremely sensitive and become exceedingly dangerous, the slightest shock causing a violent explosion. Decomposition may be detected by its turning a greenish color or by its changing blue litmus paper to red. In a frozen state nitroglycerin becomes insensitive and is safely handled in that condition.

The incompressibility of liquid nitroglycerin is a dangerous quality and the liquid is inconvenient to handle. To make it safer and more convenient some material that will absorb and retain it is used. It then passes under the general name of dynamite, giant powder, etc. The igniting point of dynamite is about 360° F. Ignited in small quantities in the open air it simply burns fiercely. Large quantities would explode. Dynamite freezes at 40° F. and in this condition is not easily exploded.

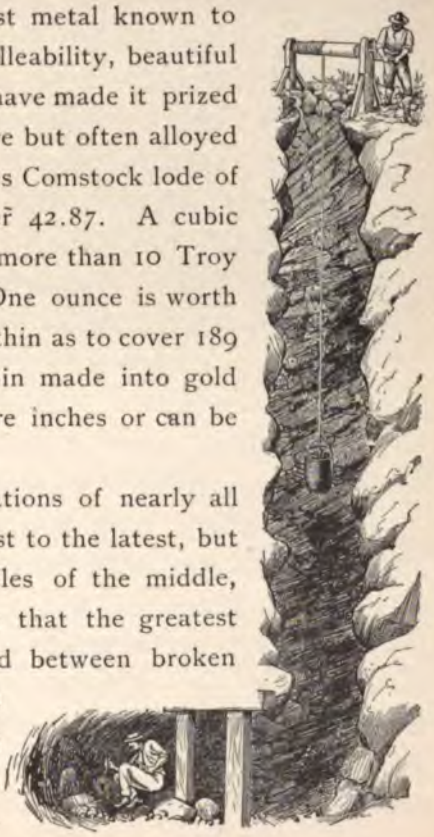
Explosive gelatin, the most powerful explosive of all, is made by dissolving by the aid of heat four to eight parts of soluble gun cotton in ninety-six to ninety-eight parts of nitroglycerin. It then becomes a honey yellow color varying in consistency from jelly to tough leather. Unconfined it burns freely but does not explode. If confined it explodes violently. Its ignition point is 399° F. if heated slowly; if heated rapidly, 464. In a frozen state it is extremely sensitive to shock; unfrozen, not very sensitive. Military explosive gelatin is made by mixing camphor with it, which increases the elasticity and makes it less sensitive to shock.

MINERAL INDUSTRIES.

Gold — Where It is Found — How Obtained — Its Use in the Arts — Its Use as Money — The Cyanide Process — The Gold Fields of South Africa — Silver — How Obtained — Largely a By-Product — Its Use in the Arts — Its Use as Money — Copper Mining — Marked Increase in the Use of Aluminum — Coal the Basis of our Industrial Life — The World's Coal Production and its Equivalent in Man Power — Natural Gas — Gas Manufacturing — Water Gas — Fuel Gas — Coal Tar — Petroleum — First Oil Wells — How Oil Wells are Drilled — The Largest Oil Well in the World — John D. Rockefeller's Defense of the Standard Oil Company. — The Wells Light.

GOLD.

GOLD was probably the earliest metal known to man, and its ductility, malleability, beautiful appearance, and indestructibility have made it prized in all ages. It is rarely found pure but often alloyed with silver; portions of the famous Comstock lode of Nevada assaying gold 55.37, silver 42.87. A cubic inch of pure gold weighs a little more than 10 Troy ounces and is worth $209.38. One ounce is worth $20.67 and can be beaten out so thin as to cover 189 square feet of surface. One grain made into gold leaf will cover more than 50 square inches or can be drawn into wire 500 feet long.



Gold occurs in the rock formations of nearly all geological periods, from the earliest to the latest, but it is chiefly in the slates and shales of the middle, secondary, and paleozoic periods that the greatest deposits lie. When gold is found between broken strata it is usually associated with quartz and the veins vary in width from a few inches to several feet.

Placers are the superficial de-

posits of sediment by the action of water. Veins occur where, owing to some convulsion of nature, cracks have been made in the strata and gold with its accompanying medium (veinstone) is forced into the crack. A vein is usually vertical or nearly vertical, and exhibits many vagaries. One side may be fairly rich in gold and the other side, but a few inches away, barren. In general, gold in veins is found in "chutes" or "chimneys" extending nearly vertical. A quartz vein hundreds of feet in length may have in it a gold bearing column only a few feet long but extending vertically hundreds of feet. Geologists explain these chutes or chimneys on the theory that hot water or vapors once escaped through fissures in the rock and lined their passageway with gold as soot is deposited in a chimney.

Gold as it occurs in nature is either "free-milling" or "rebellious." The former is so denominated because it is easily extracted from its ores, as metallic gold or as a simple salt of the metal which yields readily to reduction. Rebellious ores are those in which it is especially difficult to separate the gold they contain into a metallic form. Deposits which contain gold in so slight a quantity that the gold obtained does not pay for its removal are also called rebellious. There are vast deposits of this class; for even a ton of sea water holds one grain of gold in solution, and the brick clay underlying the city of Philadelphia contains gold. Improved methods may eventually render it profitable to work them.

Placer Mining is certainly the cheapest, simplest, and probably the oldest method of obtaining gold. It was the method employed by the North Bloomfield Mining Company of North California and allowed them to pay dividends on deposits that assayed but 3 cents per cubic yard. Prospecting, searching for new ore deposits, is nearly all done by the placer method. The prospectors usually go in pairs, pausing to wash out a panful of dirt here and there wherever their practiced eyes find any indications of gold.

Panning is the simplest method of mining, for all the tools required are a large, shallow iron pan and a shovel. A shovelful of earth is placed in the pan, the pan nearly filled with water, and a vigorous rotary motion given to it, which dissolves the earth and throws the mud and gravel out over the edge of the pan. The gold, if there is any, being heavy, sinks to the bottom and the process is continued until nothing remains but the few glittering specks of gold in the bottom of the pan. The method is slow and laborious but is the first employed in any new field, and many fortunes have been made by it.

The rocker, a piece of mining apparatus, resembling a flat cradle with a handle at one corner, is set so that the head is higher than the foot and has across the lower end a strip of rawhide with the hair on, the hair pointing toward the head of the cradle. A few shovelfuls of earth are thrown in, the water added gradually, and the cradle shaken. The material that is lightest and presents most surface to the action of the water is carried away. The heavier parts sink; the gold, if any, goes to the bottom. If the miner calls chemistry to his aid and sprinkles mercury on the rawhide he increases the returns; for mercury has a great affinity for gold and absorbs all that comes within its reach.

The "long tom" is a rocker drawn out to many times its original length to afford greater capacity and a chance for a more thorough washing of the materials. Placer mining is available only for the gold that has been torn out of the veins and deposited by the action of water.

Hydraulic Mining. The prospector with his pan, rocker, and "long tom" skimmed over the surface and left untouched the gravel beds of ancient streams that are frequently covered by beds of lava. The bulk of gold in California and Australia is now obtained from ancient valleys, narrow channels or depressions guarded by walls of

rock which must be pierced to get to the deposit. This is often done by running a tunnel from a lower adjoining valley so as to get the necessary grade to carry away the material and the water used in washing it out. This form of mining, known as hydraulic mining, originated in California in 1852, and the most gigantic mining engineering feats are displayed in connection with it. Millions of dollars are sometimes spent before the investment becomes a paying one and an abundance of water at a sufficient head, large deposits, and a situation that gives room for the disposal of the tailings or waste, are necessary. Water for this purpose has been carried 100 miles or more; mountains have been tunneled to make a passage for it, flumes have been hung along the face of precipices and inverted siphons constructed by which it was carried to the bottom of a valley and up again over the top of the next range of hills, making a dip of 2000 feet. Great dams are built to store up the water of the rainy season against the season of drought. Whole rivers are appropriated and the water delivered into working reservoirs from one to several hundred feet above the point where the nozzle is to be located. The water supply having been secured, a flume or pay channel is built to the lowest part of the deposit, having sufficient slope to allow the escaping water to carry away the material.

The North Bloomfield Company of California expended $1,250,000 to bring the water to the bed. More than 100 miles of ditches and reservoir were constructed for the water supply alone, and to reach the deposit a tunnel nearly 8000 feet long and from 6 to 8 feet wide and high was constructed. The water is carried down iron pipes to the bottom of the deposit and there delivered under a pressure of from 100 to 500 feet, the nozzle throwing streams from 2½ to 9 inches in diameter with a power sufficient to toss about, like pebbles, rocks weighing hundreds of pounds. In this way enormous quantities of the material are literally torn to pieces and the gold is

carried away in the resulting torrent of gravel and muddy water which rushes down the flume. Across the bottom of the flume timbers with narrow spaces between them are set up, or flat stones on edge, to form eddies and allow the gold to settle as the stream passes. Blankets with a hairy nap especially constructed for this purpose, or rawhides, with the hair uppermost, are fastened along the bottom, and frequently charged with mercury, which seizes the gold in passage. Washing may continue for days, weeks, or months and then the time for a "clean-up" comes. The water is stopped and as soon as the flume is dry the rawhides, blankets, and so on, are taken up, shaken over clean sheets or rubber blankets, the gold amalgam obtained, put into a still, the mercury distilled, condensed, and made ready for use again, and the gold heated and fused into a solid ingot ready for market.

The enormous power of the streams used almost surpasses belief. The late Stephen J. Field, in speaking of them at a supper at which several noted men were present, found his remarks received with good-natured incredulity and for his hearers' benefit set about gathering information. He says, "At the Spring Valley Hydraulic Gold Mine, in Cherokee, Butte Co., Cal., our largest stream was through an 8-inch nozzle under 311 feet vertical pressure, delivered by about ½ mile of 2½ foot iron pipe, and I have seen one of those streams, at, say, 20 feet from the nozzle, move a bowlder weighing 2 tons in a sluggish way, and throw a rock of 500 pounds as a man throws a 20-pound weight. No man that ever lived could strike a bar through one of these streams within 20 feet of discharge, and a human being struck by such a stream would be instantly killed, pounded into a shapeless mass."

The pan, the rocker, the long tom, and hydraulic mining are suited only in placer mines, which, though at times rich, are soon exhausted, yet these surface deposits are often guides to rich ore deposits contained in veins.

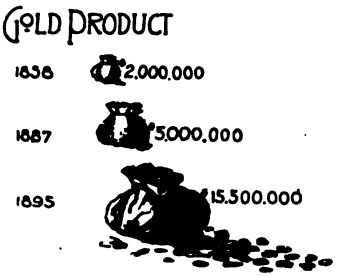
Shaft Mining. The outcropping of the vein being found, if considered rich enough to warrant the outlay, a shaft is sunk deep enough to reach the vein in its pristine condition, and the system of mining adapted to the conditions is begun. Some shafts are sunk to enormous depths, and veins are frequently worked more than 2000 feet below the surface and yield fabulous amounts. The Eureka, a quartz mine of Colorado, paid more than $2,000,000 in dividends in less than 10 years. The Idaho, a mine adjoining it, was worked to a depth of 2100 feet and paid $1,250,000 in five years.

Reduction of Ore. When the gold-bearing rock is raised to the surface it is reduced by crushers or stamps. Crushers are strong machines with a pair of heavy jaws faced with case-hardened steel; the jaws open wide enough at the top to take in the largest pieces of rock from the mine, and at the bottom approach to a narrow slit. As the jaws close, the rock is broken somewhat, and when the jaws are opened it falls a little to be again crushed until it emerges through the slit almost as fine as powder. One machine can crush from 400 to 500 tons of rock in a day.

Stamp mills divide the ore more finely and render accessible smaller particles of gold. The stamps are like gigantic mortars and pestles, the latter being able to strike a blow of 30 tons or more. They are arranged along in a row or battery and steam or water power is employed to run them. The ore is fed into the trough, which serves as a common mortar for all the pestles, being divided as it passes from one stamp to another until it emerges mixed with water as "slime." Various machines, known as vanners, jiggers, tables, rotaries, and many others, each suited to a special case, are employed to "concentrate" the slime, though, if it is free-milling ore, there is usually mixed with it while under the stamps, mercury, which unites with all the gold with which it comes in contact, and by passing the pulp or slime from the battery over an amalgamated cop-

per plate the gold amalgam is "held out." The slime is then passed over to the concentrating machines, which separate the gold from the rest of the rock, and the residue is smelted, chlorinated, cyanided, according to the method deemed best for the particular case.

Gold nuggets of great size are uncommon and their discovery is pure luck. Usually there is not much gold in their immediate vicinity and they seem to be strangers who have drifted from their homes and preserved their identity because of their great size. Miners, toiling for years with poor results, have been known to go mad on unearthing a big nugget. Superstitious miners believe that bad luck frequently accompanies the nugget and there are many remarkable coincidences well calculated to strengthen their belief.



COLORADO.

The largest nugget ever found is accredited to New Zealand, where, in 1852, one weighing 223 pounds 4 ounces is said to have been found and sold for $55,000.

Australia seems to have produced the greatest number of large nuggets. The famous "Blanch Barkly" weighed 146 pounds. The "Ballarat" nugget weighed 184 pounds 8 ounces and sold for $41,000.

The largest American nugget was probably that found at Camp Corona, Tuolumne County, California, November 18, 1854. Oliver Martin and a partner had prospected for months without success, and severe weather coming on, the partner, unable to withstand the privations, sickened and died. Martin, weak as he was, tried to give him a decent burial and began digging a grave at the foot of a tree, when he unearthed a nugget as thick as a man's body. He was so weak he could not get it out of the ground, so covered it up, and

burying his friend near by set out for help to secure his treasure. The nugget weighed 151 pounds 6 ounces, and sold for $36,270.

One Daniel Hill had more than his share of luck. In 1866 he found a nugget which sold for $17,000 and in 1871 one which sold for $14,000. Perhaps his find "drove him to drink" for he died in jail of delirium tremens.

Cyanide Process. Early in the nineteenth century it was known that potassium cyanide would dissolve gold and the method was used for years in gold plating. In 1887 patents were issued in Great Britain, and in 1889 in the United States, to McArthur and Forrest, for a "cyanide process" of treating gold ore. They roasted with an alkali or alkaline salts the ore to be treated, employed a dilute solution of potassium cyanide, and precipitated the gold out of the solution by the use of the zinc. This method obtains from 90 per cent. to 97 per cent. of the gold present and has made valuable, mines that cannot be profitably worked by any other existing methods.

THE PROSPECTOR.

If the cyanide process had not been discovered the late South African war would probably never have taken place, for the Witwatersrand mines of South Africa were not especially profitable until the cyanide process was put in operation there. There are more than forty cyanide plants in South Africa and the cyanide process is best adapted to the working of those ores that are the least suited to other methods. It is easy enough to get the gold into a solution, the cyanide solution does that, but the trouble comes in ridding the solution of its gold. Many methods have been devised for the purpose, the fact that there are so many showing that few of them are satisfactory. Several methods are employed to precipitate the

gold contained in the solution,— one by sending an electric current through it; another by adding zinc shavings and an excess of potassium cyanide, when the gold unites with the zinc and is heated to a red heat, which oxidizes the zinc and leaves the pure gold behind. There are numerous modifications of the method, each requiring the highest skill in their adaptation to the particular kind of work in hand, but the process in one form and another has grown until the Witwatersrand produced in 1897, just before the outbreak of the war, 3,034,678 ounces of gold valued at $62,726,794.26.

SILVER.

Silver was one of the earliest metals known to man and is very widely distributed. A list of 122 metalliferous minerals, exclusive of silver ores, analyzed, showed silver to be present. It is found in sea water, and it is calculated that the ocean contains at least 2,000,000 tons of the metal. It is found associated with all native gold ores, ranging from less than 1 per cent. to nearly 50 per cent. The silver ores of the Comstock lode of Nevada contain about 43 per cent. of silver. The gold of California averages about 12 per cent. of silver. It is an important constituent of most copper mines, often constituting about 10 per cent., the great Anaconda mine of Montana producing in three years more than 40,000,000 ounces of silver as a by-product, or nearly as much as the whole world produced for 1871.

HOTEL IN NEW MINING CAMP.

The greater part of commercial lead is obtained from galena (lead and sulphur), and silver is nearly always associated with galena.

Silver is also found with sulphur, arsenic, antimony, chlorine, bromine, and iodine.

The production of silver has greatly increased within the past century, aided largely by improved mining machinery and improvements in the chemistry of mining, which allowed it to be separated from the other substances with which it was found in combination, for some lead ores can now be worked for silver that contain less than one third the amount necessary for profitable working half a century ago, and as the demand for lead has enormously increased, an increased production of silver was of necessity bound to follow.

The first ten years of the nineteenth century the world used 91,000 tons of copper. The last ten years of the same century saw 3,643,000 tons used, and it is estimated that at least 25 per cent. of copper is obtained as a by-product from the refining of gold and silver. Associated as silver is with such a large variety of minerals, its production has been materially increased by the improved methods of obtaining each mineral. It possesses, in this respect, a marked advantage over gold, which is not so widely associated with other metals.

Silver in the Arts. While some inventions have greatly increased the production of silver, others have tended to make it less widely used in the arts. Silver was once highly esteemed for table service, and silver plate was looked upon almost as a profitable *investment*, but in modern times solid silverware has been to a very great extent replaced by wares covered with a layer of pure silver by the electroplating process. Within the last quarter-century, aluminum, once far more valuable than silver, has been produced so cheaply that it is now taking the place of silver to a marked extent in toilet articles, gilding, etc.

The following table shows the production of silver and gold for a period of years and the ratio of silver to gold by weight.

PRODUCTION OF GOLD AND SILVER FROM 1493 TO 1872.

	Estimated by Dr. Adolph Soetbeer. (ozs. of Gold)	(ozs. of Silver)	Ratio of Silver to Gold
1493–1520	5,221,160	42,309,400	8 to 1
1521–1544	5,524,656	69,598,320	12 " 1
1545–1560	4,377,544	160,287,040	36 " 1
1561–1580	4,398,120	192,578,500	43 " 1
1581–1600	4,745,340	269,352,700	56 " 1
1601–1620	5,478,360	271,924,700	48 " 1
1621–1640	5,336,900	253,084,800	47 " 1
1641–1660	5,639,110	235,530,900	41 " 1
1661–1680	6,954,180	216,691,000	31 " 1
1681–1700	6,921,895	219,841,700	31 " 1
1701–1720	8,243,260	228,650,800	27 " 1
1721–1740	12,268,440	277,261,600	22 " 1
1741–1760	15,824,230	342,812,235	21 " 1
1761–1780	13,313,315	419,711,820	31 " 1
1781–1800	11,438,970	565,235,580	49 " 1
1801–1810	5,715,627	287,469,225	50 " 1
1811–1820	3,679,568	173,857,555	47 " 1
1821–1830	4,570,444	148,070,040	32 " 1
1831–1840	6,522,913	191,758,675	29 " 1
1841–1850	17,605,018	250,903,422	14 " 1
1851–1855	32,051,621	142,442,986	4 " 1
1856–1860	32,431,312	145,447,142	4 " 1
1861–1865	29,747,913	177,009,862	6 " 1
1866–1870	31,350,430	215,257,914	6 " 1
1871–1872	11,182,028	126,634,028	11 " 1

The last edition of the Universal Cyclopædia gives the following table:—

Years	Annual Product, Kilogrammes Gold	Silver	Ratio of Silver to Gold by weight
1871 to 1875, mean	173,904	1,969,425	11.3
1876	165,956	2,323,779	14.0
1877	179,445	2,388,612	13.3
1878	185,847	2,551,364	13.7
1879	167,307	2,507,507	15.0
1880	163,515	2,479,998	15.2
1881	158,864	2,592,639	16.3
1882	148,475	2,769,065	18.6
1883	144,727	2,746,123	19.0
1884	153,193	2,788,727	18.2
1885	159,289	2,993,805	18.8
1886	159,741	2,902,471	18.2
1887	159,155	2,990,398	18.8
1888	159,809	3,385,606	21.2
1889	185,809	3,901,809	21.0
1890	181,256	4,180,532	23.1
1891	189,824	4,479,649	23.6
1892	196,234	4,945,237	25.1
1893	236,570	5,031,488	21.3

Silver versus Gold. Since the last date given above the lessened demand for silver and improvements in methods, which have rendered it profitable to work low grade gold ores, have increased the relative production of gold. The greater rapidity with which gold is obtained by placer mining sometimes influenced the legal relation of value between those two metals and its bearing upon prices, commerce, and civilization. The relative value of gold and silver as fixed by law or commerce has varied widely. Silver was produced largely in Europe and gold largely in Asia, and it naturally followed that the metal had a higher relative value in the land where it was not produced. Thus in 1717 the ratio in Europe was as 15 to 1, in China and Japan as 9 to 1. Egyptian records dating back to 1600 B. C. give a ratio of 13.33 to 1. Japan when opened to commerce in 1854 valued silver much higher than did Europeans, and traders took advantage of this to exchange silver for gold and carry millions of dollars of the yellow metal out of that country. In nearly all silver ores there is some gold, and in nearly all gold ores some silver. In three hundred and fifty million dollars' worth of metal produced from the Comstock lode of Nevada, nearly one half in value consisted of gold. For this and other reasons it is impossible to determine the original average cost of producing gold and silver from all the mines during any reasonably long period of time. If recent statistics are to be trusted, both metals are produced on an average at a loss. Such is alleged to have been the case in California, Australia, and Nevada, countries whose combined product has equaled in value nearly $3,000,000,000.

On the Dump.

In the principal producing countries — the United States, Mex-

ico, Chili, and Peru — mining is free and there are no official returns of the production, which is therefore a mere matter of conjecture. In the United States it is customary to value the silver bullion at one sixteenth that of gold. This unduly swells the value of the conjectural product of this country more than one fourth.

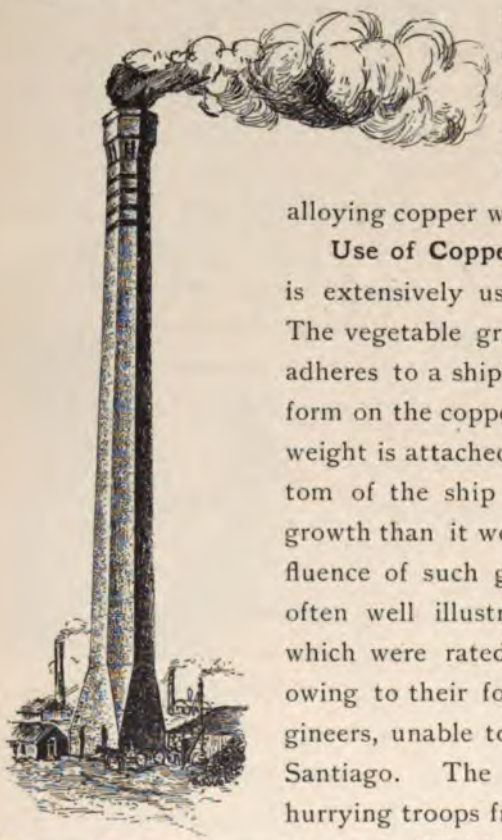
Inquiries as to the quantities of silver used in the arts have met with little success, and statistics so obtained are defective; but the total production of silver in the western world being estimated at $7,000,000,000, about $1,500,000,000 remains in coins, consequently nearly four fifths have been consumed in the arts, lost, and so on, or exported. On the whole it appears quite safe to estimate the average consumption of silver in the arts and through wear and tear and loss as fully equal to three fourths of the production. Hence it is evident that any influence tending to lessen or increase considerably the use of silver in the arts would affect materially the amount available for coinage.

COPPER.

Copper, a metallic element widely distributed, was one of the first metals used by man. The Romans obtained it from the Island of Cyprus, from which its Latin name, *cuprum*, was derived. The development of electrical engineering has greatly increased the demand for copper, for next to silver it is the best conductor of electricity, pure copper standing about 93 in a table where silver stands at 100, and its remarkable ductility makes it easy to manufacture it into wire for electrical conductors. Copper wire is the core of every submarine cable.

Alloys. Numerous alloys of copper are highly useful in the arts. *Brass* is copper alloyed with from 25 per cent. to 35 per cent. of tin. *Gun metal*, copper and 10 per cent. of tin. *Bell metal*, copper with about 25 per cent. of tin; a little zinc is sometimes

added. *Bronze*, about 91 per cent. copper, 2 per cent. tin, 6 per cent. zinc, 1 per cent. lead. Pure copper mixed with 3 per cent. of aluminum produces an alloy that is whiter than aluminum and resembles silver, but mixed with 5 per cent. to 10 per cent. of aluminum the alloy has a rich gold color, is very hard, elastic, and does service under the name of "aluminum bronze." *German silver* is made by alloying copper with nickel and zinc.



HIGHEST CHIMNEY IN THE WORLD, 352 FEET HIGH, DENVER, COL.

Use of Copper in Shipbuilding. Copper is extensively used as sheathing for ships. The vegetable growth of tropical waters that adheres to a ship's bottom causes a scale to form on the copper, which falls off when much weight is attached to it. This keeps the bottom of the ship much freer from vegetable growth than it would otherwise be. The influence of such growth on a ship's speed is often well illustrated. The Spanish ships, which were rated at 20 knots an hour, were, owing to their foul bottoms and Spanish engineers, unable to make 15 knots an hour off Santiago. The British battle ship *Terrible*, hurrying troops from Hong Kong to Taku to rescue the British in Pekin, made the distance, 1800 miles, at a speed of only 13½ knots an hour instead of the 22 knot speed of her trial trip. This well illustrates the value of copper sheathing.

The first decade of the nineteenth century used 91,000 tons of copper, the last ten years, 3,643,000 tons. The copper production

of the world for 1899 was 468,347 tons of 2240 pounds each, of which the United States produced a trifle more than 55 per cent. Of the production of the United States more than two thirds comes from Michigan and Montana, and each state is represented by a mine famous the world over,— Michigan by the Calumet and Hecla, Montana by the Anaconda. The Anaconda mine produced in the three years, 1895 to 1898, 550,962 tons of copper, 40,658,103 ounces of silver, and 135,244 ounces of gold.

Lake Superior Mines. The copper mines of the Lake Superior district have been famous for many years and the presence of copper was discovered there by Father Marquette in 1660. The copper ore is there found in veins lying at an angle of about 45 degrees. To reach the veins, shafts of enormous size have been sunk.

The Red Jacket shaft of the Calumet and Hecla Company, 14 feet by 22½ feet in cross section, is 4900 feet deep, or almost a mile, and is probably the deepest shaft in the world, its depth being exceeded only by some artesian wells. A shaft in the Tamarack, a neighboring mine, when completed will be 6000 feet. According to preconceived ideas the temperature in the Red Jacket shaft should increase with the depth, but, strange to say, the temperature at the bottom never varies far from 70 degrees Fahrenheit. The vein containing the ore is about 8 to 10 feet wide and the shaft is divided into six compartments, in each of which a load of 10 tons can be hoisted at the rate of 1500 feet per minute, making a total hoisting capacity of the shaft of 180,000,000 foot-pounds a minute. For this purpose, extremely powerful engines are employed, and each engine is duplicated so that the shaft may never be blocked in case of an accident to an engine.

Copper Refining. The copper ore as it comes from the mines is crushed and smelted into impure copper, which is cast into ingots or cakes called "blister copper." In this condition it always contains

considerable silver and usually a little gold together with other metallic impurities, such as arsenic, etc. These cakes are sent to the refineries, where as many of the impurities as can be profitably removed are taken out, for very nearly pure copper is required in the arts, and minute fractions of one per cent. of some impurities would make a marked difference in its power to conduct electricity.

The electrolytic method of refining copper is now the one by which more than half the refined copper of the United States is produced. It was patented by James Elkington in 1867, but the method was not employed in the great copper refineries until about 1887. Within a few years a considerable reduction in the cost of refining copper has been made, due chiefly to economy in the use of power and the handling of the material.

When the blister copper is received at the refinery, samples are assayed and the cakes are then cast into plates (anodes) weighing about 275 pounds each. These are suspended in tanks in a fluid consisting of a 16 per cent. solution of bluestone (copper sulphate) to which 5 per cent. of sulphuric acid is added. The cathode plates for the battery are made of pure copper sheets .04 inch thick. The method is similar to that employed in electroplating. When the electric current is turned on, the copper in the solution is set free and deposited on the cathode sheet. The sulphuric acid freed by the reaction attacks the anode and forms more copper sulphate. The solution is carefully watched, tested, and kept up to the standard. When the anode plates are destroyed the current is stopped, the cathodes removed, cleaned, melted, and cast into any form desired for the market. The gold, silver, and copper from the anodes fall to the bottom of the tank during the electrolytic action and form what are known to the trade as "slimes." The pieces of the anodes are screened out and remelted, and the slimes are treated by various processes which recover the gold, silver, copper sulphate, and arsenic.

ALUMINUM.

In 1724 a German chemist named Hoffman declared that the bases of the alkaline earths were metals, and some were soon recognized, but aluminum was so elusive that it was not until 1754 that Margraff proved its existence, and not until 1854 that St. Claire de Ville of Paris was able to produce a bar of the metal. The Paris Exposition of 1865 exhibited a bar of it labeled "Silver from Clay." It then cost $200 a pound. Improved methods have greatly reduced its cost until it is now a familiar object and has quite an extensive use in the arts. Next to silicon it is the most abundant of metals, being found in every clay bank and the cost of reducing it to the metallic state is all that keeps up the price, for no such thing occurs in nature as an aluminum nugget or aluminum dust. Professor Clarke of Washington estimates that the crust of the earth contains 7.81 per cent. of aluminum and 5.46 per cent. of iron, and if aluminum were as easy of reduction as iron, it would cost much less than the latter metal.

Distribution. Aluminum exists in the greatest quantities on the surface, which is accounted for upon the supposition that when the earth's crust was in a fluid form, the lighter metals floated on the surface, and as aluminum was one of the lightest it was caught in the top layer when the crust solidified.

Common clay, a mixture of about half silica and half alumina (aluminum and oxygen) with a little water and some minor substances, does not seem closely related to the precious stones but amethysts, sapphires, rubies, and topazes are only forms of alumina. Mica contains 20 per cent. of alumina, clay 21 per cent., emery 31½ per cent., corundum 52½ per cent., bauxite, the usual ore from which the metal is now reduced, from 28 to 31¼ per cent. Emery and corundum, although rich in aluminum, are valuable in themselves as abrasives. Aluminum cannot be easily derived from clay because

the oxygen holds it in too firm a grasp, so bauxite ($H_6Al_2O_6$) is the common source. Aluminum ranks after silver, gold, and platinum as the least alterable of the metals.

Aluminum is only 2 ½ times as heavy as water, while iron is 7 ½ times as heavy, copper 9 times, lead 11 times, and gold 19 times. Its electrical conductivity compared with silver is 50, and it can be beaten into sheets 5-100,000 of an inch thick, in which form it is used in book making.

The following table shows how the price of aluminum has fallen with improvements in the methods of extracting it:—

1855	$200.00 a pound	1888	$5.00 a pound
1856	82.00 " "	1890	3.00 " "
1857	21.00 " "	1891	.50 " "
1860	12.00 " "	1893	.40 " "
1883	8.50 " "	1900	.33 " "
1887	8.00 " "		

Methods of Extraction. Charles M. Hall of Oberlin, Ohio, and Heroult of France, each independently and at about the same time, April 2, 1889, devised very simple methods for the extraction of aluminum. The Hall method uses a containing vessel lined with carbon, the lining of which serves as the cathode for the electric current. Suspended in the middle of the container is another piece of carbon, the anode, that does not touch the sides. When the electric current is forced through, the anode is slowly oxidized. Into the container is put a mixture of the fluorides of aluminum and sodium, two poor conductors of electricity, and when they have been melted by the heat of the electric current, alumina (aluminum oxide, Al_2O_3) is shoveled into the bath and at once dissolved. The current attacks the alumina and separates it from the oxygen. Hall's method, first established on a considerable scale in 1888, has greatly reduced the price of the metal.

COAL.

It is hardly necessary to say that coal represents the heat of the sun absorbed by the growth of vegetation of a time long past, which later, buried under water, earth, or rock, underwent a process of decomposition and distillation, and produced the dark, unassuming object sometimes called "bottled sunshine" and "black slave." Some idea of the wonderful luxuriance of the forests of the coal age may be formed when we consider that if the forests of to-day were to be put through the same process they would yield a layer of coal only two or three inches thick, while some coal beds of Germany aggregate nearly 300 feet, and in the United States single veins are found from 60 to 100 feet in thickness.

On the Tramway.

Its Contribution to Civilization. This dark shiny object, so familiar that it often attracts no attention, contains within it wonderful possibilities and has a most fascinating history. If it had not been discovered and utilized, much of our boasted civilization of the twentieth century would be impossible. It serves man in many ways, for its sphere of usefulness is not restricted to furnishing heat, and its derivatives are almost innumerable. In short, it sometimes seems as though almost any chemical compound present in existing vegetation can be duplicated in that of a pre-historic age. Coal, with its history, its chemical compounds, its latent force, claims at once the attention of the botanist, the zoölogist, the chemist, the physicist, the physician, and the manufacturer.

The coal beds have preserved so well the exact outline of the ferns, the leaves of the trees, the grains of the wood, the mosses on

the bark, and the forms of animal life then existing, that the scientist is better acquainted with the flora and fauna of the carboniferous age than the average layman is with that of the present.

Mineral coal is part of a long series beginning with woody fiber and ending with graphite. Different stages in its manufacture are represented by *peat*, *lignite*, *bituminous coal*, *anthracite coal*, *asphaltum*, and *graphite*. Among the other products are petroleum and carbonic acid and carbureted hydrogen gases.

Peat is formed in morasses and bogs by accumulating decayed vegetable matter until the bottom layers become darker and denser, have some of the gaseous elements driven out by pressure, and partake of the nature of coal. A vertical section of a peat bog shows every stage of the process. Peat is extensively used for fuel in some countries but it is inferior to lignite.

Lignite is the next step, and represents vegetable fiber from which more of its gaseous substances have been distilled. It shades off from brown woody fiber into bituminous coal, and in general may be said to come between peat and true coal. The heat value of lignite is greater than that of peat, but in general less than that of the true coal, although some of the best lignites are better than the poorer coals. The most of the coals found in the western part of the North American continent are classed as lignites, and it is interesting to note that portions of lignite beds which have been subjected to great heat and pressure, as from volcanic sources, have sometimes been developed into true anthracite with its characteristic hardness and glitter.

Bituminous coals (soft coals) are the products of a slow distillation which has rid the fiber of more of its gaseous constituents than in lignite and have not been subjected to the enormous pressure and influence of heat that produce the anthracite. The volatile matter of bituminous coal ranges from about 18 per cent. to 50 per cent. of

the mass. *Coke* is made from that grade of bituminous coal which will cake or melt and adhere into a mass when burning. *Furnace* coals are those that do not exhibit this caking feature when burning and can therefore be used in blast furnaces. *Cannel* coal is rich in gas but poor in heating power and is a favorite household fuel for the open grate. Coking coals and cannel coals are not adapted to iron smelting.

Anthracite is the hardest variety of coal and has a characteristic glitter that the softer grades do not possess. Anthracite is coal that has been subjected to greater heat and pressure and has so driven off more of the volatile elements, until it contains only 3 per cent. to 5 per cent. of volatile matter and frequently 95 per cent. or more of pure carbon. It burns slowly, emitting intense heat, little flame, and almost no smoke. China is said to possess considerable fields of anthracite yet unexploited.

Pennsylvania produces 53 times as much anthracite as all the rest of the world, yet nature has wasted 99 per cent. of what Pennsylvania once had, for the coal now left in the hills of Pennsylvania was once the bottoms of the valleys. Geologists have said that at a remote period the coal bearing strata of that state were thrown up into vast undulations or huge wrinkles, and that the action of the weather and the water washed down the higher parts and deposited them in the valleys and in the sea. The water courses formed where the greatest wear had been, with the result that rivers now flow where mountains once stood and mountains now stand where valleys once were, and in this wear and tear all but about one per cent. of the original coal deposits were torn down and deposited as "ooze" in the valleys and the sea.

The anthracite production of the United States is equal to its gold and silver supply, and when we consider how vitally important coal is in the production of iron and steel and for furnishing power for

factories the question may well be asked, is not the coal of as much importance as the precious metals?

Graphite is coal deprived of all its gaseous matter, retaining but little of its carbon together with all its ash. It is practically incombustible and of no use as a fuel.

Coke Manufacture. When bituminous coal is heated in an oven nearly all the volatile matter is drawn off and the remainder is known as coke. Only those kinds of bituminous coal are available for coke that melt and run together when heated. Coke is hard and gives a ringing sound when struck, and is spongy, due to the formation of the gas. When manufactured as a by-product at gas plants it is used for heating or the production of steam. Coke, especially manufactured, is used to melt pig iron in cupolas and smelt iron, copper, or lead in blast furnaces. Coke was first successfully used in the manufacture of pig iron by Abraham Darby of England in 1735, and although he produced an excellent quality of iron, the charcoal interests raised such a hue and cry that it did not come into general use for some years. William Firmstone is credited with having been the first (1835) in the United States to make pig iron from coke.

Coking in England and the United States is carried on in the "beehive" oven. The beehive is 10 or 12 feet in diameter, and from 6 to 8 feet high, usually built of stone and lined with fire brick. There is an opening at the top for the escape of the gases and the admission of the charge and one at the side closed by an iron door through which the finished product is drawn. The average charge is 3½ to 4 tons of raw coal. The first time the oven is charged it is necessary to ignite it, but after the oven is once started, the heat from the adjacent walls ignites the gases in the coal, causing a puff like a powder explosion. After 24 hours the air supply is shut off, and nothing left but the holes for the escape of the gas. Furnace coke is heated about 48 hours and foundry coke about 72 hours.

The ovens are arranged in the form of numerous cavities in a bank, having steps like a terrace. On the top step runs a track carrying the cars or carts of coal which charge the ovens through openings in the top. On the second step are the workmen, who with iron rakes draw out the coke, quench it with water and load it into freight cars on the step below. The coal is not consumed, but, like the process of converting wood into charcoal, only burned enough to drive off the volatile matter.

Continental Europe is much ahead of Great Britain and the United States in the economical management of her coke ovens, which are massive structures of fire brick with side and bottom flues arranged to utilize and consume gases wasted by the beehive method. They work much quicker, yield more coke from a given amount of coal, and are able to use coal of a poorer grade. The utilization of the by-products has become so important that some concerns offer to convert coal into coke in exchange for the permission to utilize the waste gases, tar, and ammonia.

The United States census report of 1850 shows but four coke-making establishments and these were at Connellsville, Pa. The industry grew rapidly, and in 1871 the H. C. Frick Coke Company was organized, which now controls the output of that region. The company, consisting of H. C. Frick, A. O. Tinsman, and Joseph Rist, purchased 300 acres of land near Mount Pleasant and erected 50 ovens. In 1900 it had grown to a capitalization of $10,000,000, and controlled 80 per cent. of the 20,462 ovens, employing 25,000 men, in operation in that region,—a wonderful tribute to the energy and executive ability of the managers. The Connellsville region has been the scene of much violence, but the coal lands which 25 or 30 years ago were selling for $15 an acre are now bringing from $2000 to $3000 an acre and are hard to get at that price.

Coal Supply and Consumption. When we consider the enormous

rapidity with which the consumption of coal is increasing, the supply of the world's fuel may well merit a little consideration. In 1831 the annual coal production of Great Britain was 24,000,000 tons. The estimated production of 1901 was 240,000,000 tons. In 1831 Great Britain consumed one ton of coal for each inhabitant. In 1901 the coal consumption was six times as great, and the rate of increase was fifteen times as great as the increase of population. In 300 years England has produced 10,101,000,000 tons of coal and it has been predicted by those who delight in taking a gloomy view of things that by 1945 her coal mines can no longer be worked at a profit and that she will be compelled to obtain her fuel from some other country, perhaps China, for in China there are vast fields of coal that have not been worked at all. Just at present the problem is receiving a great deal of attention, for the mines of Great Britain are no longer able to produce enough for the consumption of that country and Pennsylvania coal has been used to generate gas to light foggy London.

In 1840 the United States consumed about one ton of coal to every six persons. To-day she is using eighteen times as much, and the increase since 1890 alone has been more than 50 per cent. It was estimated by General Wistar some time ago that if the coal consumption of the United States increased 10 per cent. annually for 25 years, then 5 per cent. annually for 50 years and 3 per cent. annually for 25 years following, it would in 100 years, *i. e.*, in 1991, practically exhaust the estimated supply. Well, since 1891 the coal consumption has exceeded his calculations. As the magnitude of the problem dawns upon the industrial world and fuel increases in price, various economies will be practiced. It is estimated that for every ton of coal produced 1½ tons are wasted in the form of dust, slack coal, and pillars of coal left to support the roof. Considerable quantities of coal dust are now mixed with tar, pressed into bricks, and used as

fuel. The enormous volumes of gases daily going to waste from the blast furnaces can be utilized by gas engines, converted into electricity, and distributed where it will furnish motive power for factories of various kinds. Germany is doing this, but it is believed that 2,000,000 horse power is annually wasted in the escaping gases from the blast furnaces of Great Britain. In making each ton of coke, 8000 cubic feet of gas is given off and only half of it consumed. All the best plants now utilize their blast furnace gases.

Some Interesting Equivalents. Coal has crept so quietly and unobtrusively into the industrial life of the world that many of us rarely stop to consider how important it has become. Every ton of pig iron ready for export represents at least two tons of coal, and every ton of iron or steel bars, six or eight tons of coal. Our modern systems of transportation could not do without it, for it is estimated that the locomotives of the United States and Canada now consume at least 64,000,000 tons of coal annually, or as much as the annual production of the whole world not so very many years ago. One half the bituminous coal of the United States is used on railways and steamships. Trade and industry would be paralyzed if deprived of its help. Burned in the furnaces of the quadruple expansion engines of an ocean freighter, a piece of anthracite the size of a hickory nut develops power enough to propel one ton of the vessel's displacement one mile. It is not uncommon for freight carrying vessels of from 10,000 to 12,000 tons displacement, moving at from 10 to 12 knots an hour, to average from .032 to .039 of a pound of coal per ton of displacement per knot. On land the best modern engines will with one pound of coal do the work of one horse for an hour. Mulhall says, "Human energy is by common consent fixed at 300 foot-tons daily for a man, 200 for a woman, and 100 for a child between 10 and 16 years of age." If the figures of this famous statistician are correct, and if all the able-bodied working

men of the world were enslaved and compelled to labor arduously 10 hours a day 300 days in the year for the benefit of society, they could not begin to carry the burden borne by coal. One pound of coal most advantageously employed would perform the work of 33 such slaves for an hour. Suppose such a slave to be pumping water at the mouth of a mine in competition with an Allis engine:—

One pound of coal=one horse-power-hour (1,980,000 foot-pounds).
One horse-power-hour=33 man-power-hours (60,000 foot-pounds).
2240 pounds of coal=73,920 man-power-hours.
73,920 man-power-hours=7392 10-hour days of labor.
7392 10-hour days of labor=24.64 years of labor.

One ton of coal at the mouth of a mine weighs 2240 pounds and can be bought for a dollar, hence it follows that such a slave competing with a steam engine at the mouth of a mine would be required to work 24.64 years to do as much as one ton of coal, or at the rate of about four cents a year.

The world's production of coal and lignite for the last year of the nineteenth century approximated 725,000,000 tons. The earth's population is estimated at 1,500,000,000 souls. Suppose that the poorer grades of coal and lignite as nearly equal the energy contained in the best grades of coal, as the women, infants, lame, halt, and blind of the earth's population equal the power of the able-bodied men: if then this coal were consumed under the most economical conditions, it would give energy equivalent to 53,592,000,000,000 man-power-hours, to equal which, the entire population of this planet would be compelled to toil 35,728 hours or 3,572 10-hour days, or 11.9 years of 300 days labor.

To sum it up, the coal production of a single year is able to perform as much work as the entire population could do in more than 10 years. Does Civilization owe any recognition to the genius of the inventors which has brought "Steam Engine, Coal & Co." to

such a high state of efficiency that the world's commerce has increased more than 1200 per cent. in a century, while its population has only rather more than doubled? Yet all this is not obtained without effort or danger, and the coal that warms a cheery home is not infrequently obtained at the risk or even loss of life or limb of a workman, who toiled hundreds of miles away, thousands of feet below the surface, and faced terrors which only the initiated can fully appreciate and understand.

Dangers and Fatalities in Mining. The report of the government inspector of British mines for the decade 1880-90 showed that, to say nothing of those injured, about one thousand miners were killed annually in the mines of Great Britain. A fertile source of accident from falling bodies are tree trunks in a vertical position, the wood of which decayed and left the bark to be turned into coal while the hollow was filled with shale, sandstone, etc. When the coal underneath is removed all that holds the mass of sandstone and shale in place is the adhesion of the thin rind of coal bark, and when this gives way the trunk falls of its own weight, frequently with disastrous results, for such formations are of frequent occurrence, and in the dim light of the mine it is often impossible to discern them. In the early days of coal mining explosions of fire damp were ascribed by the superstitious miner to supernatural agencies. Near the end of the eighteenth century Spedding discovered that a red heat would not ignite fire damp; it must be brought in actual contact with flame. Humboldt in 1796 and Clanny in 1806 invented lamps in which the air that fed the flame was made to bubble up through a liquid, but the lamp was cumbersome, expensive, unpopular, and the workmen, ignorant and heedless, went on merrily with their naked lights until Sir Humphry Davy in 1815 brought out his safety lamp. That invention with its improvements has saved thousands of lives, for "The introduction or exposure of a naked light for even so much

as a second is sufficient to cause an explosion of the mass. Doors are blown down, props and tubbing are charred up, and the volume of smoke rushing up by the nearest shaft and overthrowing the engine house and other structures at the mouth conveys its own sad message to those at the surface, of the dreadful catastrophe that has happened below. Perhaps all that remains of some of the workers consists of charred and scorched bodies scarcely recognizable as human beings. Others escape with scorched arms or legs and singed hair to tell the terrible tale to those who were more fortunately absent." * To render the calamity, if possible, still worse, a flood of choke damp (carbon dioxide) is caused by the combustion of the fire damp, and the horrors of suffocation are added to the terrible scene.

World-Production of Coal. The following table shows the world's production of coal and lignite at the close of the century. It is highly significant that three countries, the United States, Great Britain, and Germany, produce 80 per cent. of the world's coal and 70 per cent. of its iron.

Country	Years	Tons	Percentage
United States	1899	230,838,973	31.96
Great Britain	1899	220,085,303	30.47
Germany	1899	135,824,427	18.81
France	1898	32,356,104	4.48
Belgium	1899	21,917,740	3.04
Austria-Hungary	1898	37,786,963	5.23
Russia	1898	12,862,033	1.78
Sweden	1898	236,277	.03
Spain	1899	2,742,389	.38
Italy	1898	341,327	.05
Canada	1899	4,076,779	.57
South African Republic	1898	1,938,424	.27
Natal	1898	387,811	.05
India	1898	4,136,813	.57
Greece	1898	17,310	
New South Wales	1899	4,597,028	.64
Other Australasia	1898	1,601,968	.22
Japan	1897	5,647,751	.78
Algeria	1898	200	
All other countries	1899	4,849,380	.67
Total		722,245,000	100.00

* Edward A. Martin.

GAS MANUFACTURE.

"Often have I swept backward in imagination six thousand years, and stood beside our Great Ancestor, as he gazed for the first time upon the going down of the sun. What strange sensations must have swept through his bewildered mind as he watched the last departing ray of the sinking orb, unconscious whether he should ever behold its return. Wrapt in a maze of thought, strange and startling, his eye long lingers about the point at which the sun had slowly faded from his view. A mysterious darkness, hitherto unexperienced, creeps over the face of nature. The beautiful scenes of earth, which, through the swift hours of the first wonderful day of his existence, had so charmed his senses, are slowly fading one by one from his dimmed vision. A gloom deeper than that which covers earth steals across the mind of earth's solitary inhabitant."*

For thousands of years the labor of man practically ceased with the going down of the sun, and his wood fire or his torch were his first crude efforts to extend the day for his labor or amusement. The rude lamp made from a shell partly filled with the fat from the game he killed or the oil from the fish he caught, with fibers of bark or a rush for a wick, succeeded the torch. The contrast between the surrounding gloom and the dim light of such a lamp is not greater than between the lamp itself and the artificial light apparatus of to-day.

Coal Gas. If any vegetable or animal matter be inclosed in a retort and raised to a red heat it will give off gas, water, tar, and leave a residue of coke or charcoal. This is the principle employed in the manufacture of illuminating gas. Coal had been used for hundreds of years before the practical application of coal gas was made for lighting purposes. William Murdoch of Cornwall in 1792 lighted his house with gas made from coal. In 1798 he lighted the shops of

*Gen. O. M. Mitchel.

Boulton, Watt and Co., and the system gradually came into use, although some rather serious accidents retarded its rapid adoption. The House of Parliament was lighted by gas in 1813, the streets of London in 1815, and those of Paris shortly afterward. Gas was used in Baltimore in 1816, in Boston in 1822, in New York in 1825, and the manufacture of gas was probably the greatest chemical enterprise of the nineteenth century.

Process of Manufacture. In the making of coal gas, caking coal is commonly used. It does not give so rich a gas as the cannel coal, but it is abundant and cheap, and the coke produced can be used for other purposes. The coal is placed in retorts heated by a coke fire. From the retort a tube (standpipe) leads upward to the *hydraulic main*, a tube or reservoir kept half filled with tar. That the gas may not rush backward when the retort is opened, the end of the standpipe empties two or three inches below the level of the tar, which forms a gas check. In the hydraulic main the hot gas deposits a part of its ammonia, water, and tar, and then an *exhauster* working on the principle of an air pump, forces it through a series of bent tubes called the *condenser*, where it gives up more of the tar, water, and ammonia, which are led off to separate receptacles. The gas next passes through the *washer*, where jets of water remove more tar, ammonia, and sulphur, and then to the *purifier*, where lime removes the sulphur compounds and carbonic acid. From the purifier it passes to the *gas holder*, a familiar object in every city. A good illustration of the gas holder is a tumbler inverted in a basin of water, the tumbler being kept afloat by the imprisoned air underneath it. When the gas reservoir is full the gas holder is buoyed up, but as the gas is used it settles down and preserves a constant pressure of gas in the lines, a very desirable consideration.

Water gas, introduced about 1875, is produced by decomposing steam by intense heat and mixing the hydrogen evolved with carbonic

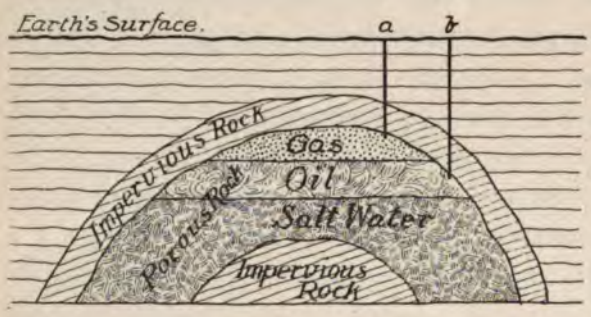
oxide gas. The resulting mixture has enough heat but little illuminating power, so it is enriched by passing it over hot coke on which crude petroleum is being volatilized. This converts the mixture into a permanent illuminating gas at much less cost than coal gas. The gas can be made as rich as desirable, but ordinarily it would appear as though the manufacturer of water gas had taken a lesson from his milkman. Water gas derives its name from the fact that three fifths of its weight and three fourths of its bulk is made up of the oxygen and hydrogen obtained from the steam. Ordinarily, it has neither the illuminating nor the heating power of coal gas and is also more poisonous.

Fuel gas, or producer gas, is a by-product in the manufacture of water gas. It is not available for lighting purposes but can be used, as its name indicates, for fuel, although it has not the heating power of either coal or water gas.

Natural gas is the gaseous form of bitumen and was known to the Fire Worshipers of Persia thousands of years ago. The burning springs of Asia Minor and fires of Baku on the shores of the Caspian have been described by travelers ever since the days of Marco Polo. On the North American Continent, burning springs were early noticed, especially by the French missionary explorers. Apparently, the first attempt to use natural gas was at Fredonia, N. Y., where in 1824 wells were dug into the rock strata and the gas utilized for heat and fuel.

Some idea of the earth's strata is necessary to understand the theories now generally accepted for natural gas and petroleum. These suppose the strata of the earth to be bent or deflected, forming folds or wrinkles. If in such a formation there is an impervious layer of rock or coal underlain by a thick stratum of porous rock or loose formation, we have, if petroleum be present, the necessary conditions for a "gas pocket." (See illustration.)

Location. Oil and gas do not lie in open and free pockets, but are held in the porous rocks as water is held in a sponge. Neither is oil always found accompanying gas, but it usually is not far distant. The gas, being lighter, is always at the top of the curve (anticline).



NATURAL GAS.

Next comes a stratum of oil held in place by the pressure of salt water of a peculiar bitter taste. In the diagram, if a well be drilled at *a*, gas will be obtained and as it is held there under pressure from the oil and water, when a vent is offered it rushes out with considerable force. If the anticline is tapped at *b*, oil instead of gas will be obtained, and if the well were continued deeper, salt water would be found. In fact, nearly every oil well yields some salt water, and some oil wells that have become exhausted, are profitably worked as salt wells. The pressure under which the gas is stored is sometimes so enormous that the flow from the wells cannot be controlled for a considerable time after gas has been "struck." It is not an uncommon thing for a strong "gaser" to shoot the whole "string of tools" out of the hole through the derrick, and when it is recalled that a string of drilling tools weighs anywhere from 2000 to 4000 pounds, the force required may be realized. The gas accompanying oil wells is frequently a troublesome factor when it comes time to lower the "torpedo" to "shoot" the well. Gas wells are drilled in the same manner as those for oil, which will be described later. The gas is conveyed from the well in a "pipe line" made of joints of iron tubing the ends of which screw into "collars," frequently form-

ing a continuous line many miles in length, enabling the gas wells of one state or province to furnish light or heat for the cities of another.

Natural gas is a poor illuminant but has great heating power, and for a time was so extensively used for manufacturing purposes, notably at Pittsburg, that it materially reduced the output of coal and became a factor in industrial life second only to coal and the steam engine. But the supply is gradually failing and manufacturers are being forced to return to coal.

PETROLEUM.

The petroleum industry, although a development of the last half century, deals with an article that has been known in other lands from time immemorial. In China it was in use before the dawn of written history, and the famous petroleum springs near Baku on the western shore of the Caspian Sea have been known from the earliest times. Pliny and Herodotus each knew or had heard of petroleum, and in the city of Genoa, centuries ago, a kind of petroleum oil was used in the rude lamps of the time.

Even gold mining, with all the romance which envelops it, cannot parallel the sudden transitions from poverty to wealth, or the speculation and feverish excitement attendant upon the development of a new oil field. Perhaps a worthy historian of the industry may arise able to do justice to the prospectors, who, like Mother Carey's chickens, have been flitting here, there, yonder, dipping now into the soil of this part of the country, now into that, or making trips to foreign lands, and all the while keeping the telegraph wires and cables hot with quivering, exciting messages to one another of their pilgrimages in search of that fascinating article, petroleum, whose by-products are almost as multitudinous as the sands of the sea.

Petroleum an Incidental Product. It seems strange that a prod-

uct now of such value was once considered by those that encountered it as big a nuisance as the forests which the early settlers cut into logs and burned to get out of the way. In the first half of the nineteenth century numerous salt wells were drilled along the western slope of the Alleghanies, and frequently the mine owners were forced to abandon the scene because of the appearance of a green slimy substance that accumulated on pools, canals, and reservoirs, greatly to their disgust. In 1854 Dr. Gesner obtained an illuminating oil from coal, and a Long Island company was formed to manufacture a species of kerosene for illuminating purposes with such startling success that within a few years there were numerous enterprises of the kind set up within the soft coal fields, destined to become obsolete and a loss to their investors because of the recognition of the value of petroleum. In 1857 twelve barrels of petroleum were shipped to New York, and this is said to be the beginning of its history as an illuminant. Never before in the history of commerce has an industry so quickly sprung into life and unparalleled activity as this. Witness the following table:—

THE CITY OF OIL TANKS.

Year	Production Barrels	Lowest Monthly Average Price	Highest Monthly Average Price	Average Yearly Price	Wells Completed
1859	1,873	$20.00	$20.00	$20.00	
1860	547,439	2.75	19.25	9.60	
1870	5,308,046	3.15	4.52½	3.89	
1880	26,027,637	.80	1.10¼	.94½	4217
1890	33,163,513	.67⅞	1.05	.86½	6435
1898	60,568,081				

Producing Areas. Now there are annually produced, according to the office of the Geological Survey, more than 5,000,000,000 gallons of petroleum, of which amount 2,500,000,000 are from the United States, 2,250,000,000 from Russia, and the remainder distributed among a dozen different countries, including Austria, 87,000,000; Sumatra, 72,000,000; Java, 30,000,000; Canada, 29,000,000. Numerous single oil wells have within twenty years produced oil to the value of more than $1,000,000, and when the capital invested is taken into consideration the dividends of the richest gold mines of the world cannot compare with the returns from the liquid wealth.

Rock Oil Company. When the value of petroleum came to be appreciated the famous Rock Oil Company, 1855-56, was the earliest in the field, but there were so many hindrances to its success that it almost became a byword. It was with this company that Edwin L. Drake was connected as an employee, afterward decorated with the title of "Colonel" to help give dignity to the company. Meeting with no success the company was afterward merged into the Seneca Oil Company with Drake as president. The company had a capital of $1000 and paid its president a salary equal to its capital and from this humble beginning in a little more than a generation sprung petroleum capitalizations equal to more than $500,000,000, with 30,000 miles of pipe line, more than 10,000 tank cars, and 100 ocean steamers.

Drake's first derrick in the Pennsylvania oil field was erected near Titusville in the summer of 1859. It was boarded to the top and resembled nothing in the world as much as a clumsy Cleopatra's needle minus its hieroglyphics. The men lived, slept, ate, worked, within this one building, and the president of the company secured accommodations for himself, his wife, two children, and the horses for about $1 a day, a fairly good indication of the wealth of the concern and the luxury of the country.

The men worked with tools weighing 300 pounds attached to a spring pole. The efforts of the workmen pulled down the end of the pole and caused the drill to strike a blow. On releasing their hold, the elastic force of the pole raised the tools ready to be drawn again for another stroke. They drilled through 47 feet of gravel and 22 feet of shale rock without success and stopped Saturday night at 70 feet. The capital and credit of the concern were about exhausted and Drake was in the depths of gloom and despair. Sunday, Drake strolled over to his well and was rendered speechless at the sight, for from the opening was issuing steadily a stream of dark and viscous wealth. The news rapidly spread and soon the hill was black with excited people running coatless, hatless, coming on horseback, or driving in on anything that would hold to wheels to view the phenomenon; and well they might be interested, for within 48 hours the well was pumping 20 barrels an hour and the oil was worth $20 a barrel. The production fell off in a few weeks to less than ten barrels a day, its total output the first calendar year being only 1800 barrels. The tools used in this first and famous well were years afterward purchased by Lewis Emery, Jr., and are now on exhibition in a museum in Bradford, Pennsylvania. The news of Drake's success spread rapidly and numerous wells followed, but they were all put down by the primitive method of the spring pole and were very shallow indeed compared with the depths now reached.

With a strange fatality that seems inseparably connected with that business, many operators stopped short, discouraged and poverty-stricken, when only 20 or 30 feet from what later developments have proved was almost fabulous wealth. For some reason Drake neglected the golden opportunities lying at his very feet and failed to secure other territory.

Present System of Operation. The inventive genius of the operators devised the present system, which came into general use

STRING OF TOOLS.

about 1866-68. It consists of a derrick about 20 feet square at the base and from 75 to 80 feet high, having in the top a pulley over which a cable passes, to one end of which is attached the "string of tools" 60 feet or more in length and weighing from 2000 to 4000 pounds. The other end of the cable is attached to a horizontal shaft upon which it is wound or unwound at will, the power being furnished by steam engines of from 15 to 25 horse power. Directly over the center of the derrick and the hole to be drilled, is one end of the *walking beam*, about 25 feet in length, balanced over the *Samson post*. The cable is clutched by a device attached to the end of the walking beam within the derrick, the other end of the walking beam being attached by a pitman to a wheel turned by the steam engine. This imparts a pumping motion to the walking beam, which raises and drops the tools a few inches and pounds the rock into fine fragments.

The usual "string of tools" is made up of a *bit* 4 feet long, 5⅝ inches in diameter, and weighing about 150 or 175 pounds. The bit, a steel drill with which the hole is pounded in the rock, is removed from time to time, heated in a blacksmith's forge, hammered into shape, and retempered. The bit screws into an *auger stem*, a shaft about 40 feet long and weighing from 1200 to 1500

pounds. The auger stem is to preserve the vertical position of the drill and by its weight give force to the blow of the bit. The *jars* are huge flat steel links 6 or 8 feet long and weighing 300 or 400 pounds, the links of which play into or slide upon each other and have a movement of about 9 or 10 inches. They divide the string of tools into two parts. Above the jars comes the *sinker-bar*, another shaft 15 to 20 feet long and weighing about 600 pounds. The weight of the sinker-bar is to give efficiency to the upward jerk of the upper half of the jars, the chief use of the jars being to loosen the bit in the hole, for if it sticks a direct pull is of little use and may break the cable, leaving the whole string of tools in the well.

PRINCIPAL DRILLING TOOLS.

1, 8-inch bit; 2, 5⅝ inch bit; 3, auger-stem; 4, jars; 5, sinker-bar; 6, rope-socket; 7, one of a pair of wrenches used in screwing tools together: 8, drilling cable held by clamps and hung from temper-screw above; 9, gauge used when dressing 8-inch bit.

Accidents frequently occur, especially at great depths. The tools may be caught by sliding strata of rock and pinched. A new bit a trifle larger than the old one may stick in the hole, or the tools or rope may break in two, leaving a mass of steel to be removed before further progress can be made. Almost anything can be removed by the proper "fishing tools," and there are innumerable clever devices designed to grasp rope, wood, or metal, and tighten their hold as they are withdrawn, and when it is remembered that all this may take place in a hole 2000 or 3000 feet deep and only 5⅝ inches in diameter something of the skill required and ingenuity exercised can be imagined.

When a hole a few feet in depth has been made the tools are removed, water is turned in if necessary, and the *bailer* or *sand-pump*, an iron tube with a valve in the bottom, is lowered. This is so con-

structed that when the tube rests in the bottom of the hole the valve opens and the pounded rock and water enter. When the sand-pump is raised, the valve closes, and the whole is drawn to the surface. The tools are lowered and the process repeated. As the well progresses, lengths of pipe or casing of nearly the same diameter as the hole are lowered and forced in to shut off the surface water and prevent caving. The casing is usually carried down until it rests on the first oil-bearing stratum of rock, known colloquially as "first sand."

"Striking Oil." If the "sand" is porous rock or more open formation and contains oil in great quantities, under heavy pressure from the salt water it may gush forth in a stream as high as the top of the derrick and flow hundreds of barrels an hour. The Matthew and Mevy wells of McDonald, Pennsylvania, the largest in the Appalachian field, are credited with a flow of 1500 barrels a day, and the late gusher struck near Beaumont, Texas, has been variously estimated at from 15,000 to 25,000 barrels per day. The wells drilled in the loose gravel formation of the Baku region, which Peter the Great wrested from Persia 200 years ago, are said to have yielded from 50,000 to 60,000 barrels daily.

"Shooting" a Well. In order to break up the porous rock and give the bottom of each well a larger draining surface a quantity of nitroglycerin ranging from 10 to 100 quarts, according to the character of the "sand," is lowered to the right depth. The well, if it does not contain enough oil, has oil poured into it to aid in confining the force of the explosion. When all is ready the *go-devil*, a cast iron weight, is dropped, which falling upon a cap explodes the nitroglycerin. The oil above the torpedo is thrown out and bursts in a column high above the derrick, descending in a greenish golden shower, producing in the sunlight a picture not easily forgotten. The oil in the immediate vicinity of the bottom of the well is driven

back in the porous rock by the force of the explosion and then the reaction forces it out and the well is to "flow."

Changes in the formation take place within surprisingly short distances and a non-productive well (duster) was drilled within 300 feet of the Mevy well at McDonald while the latter was yielding 15,000 barrels a day. Enormous prices have been paid for land that was good producing territory, for a single well during its history has been known to produce 700,000 barrels of oil valued at more than $4,000,000. Land from which farmers could scarcely wring a living and would have been glad to sell for a song, have yielded fortunes to their successful purchasers. George Noble leased 16 acres in 1860 in a little valley lying along Oil Creek, paying for the lease $600, and soon after refused $100,000 for a half interest, and his profits from his production, with the prices of crude oil ranging from $4 to $13 a barrel, ran up into the tens of thousands daily. Near Oil Creek one man bought a $50 lot and in a few weeks sold it for $5000. Not many rods away a purchaser drilled until he became discouraged and gave it up. Later developments showed that he was within 17 feet of $1,000,000. The Copley well, one of the latest (1900) Eastern gushers in West Virginia, yielded for months 100 barrels an hour, yet a well sunk only 1½ miles away proved a complete duster.

OIL WELL FLOWING AFTER HAVING BEEN SHOT.

When Drake's well was first put down near Oil City there were hundreds of farms lying along Oil Creek, from which for two generations the inhabitants had hardly obtained a decent living. Some of the ridiculous sights to be seen can be well imagined when such people were suddenly transformed into millionaires.

"**Coal Oil Johnnie.**" "Among the remarkable characters which the oil excitement brought into prominence was 'Coal Oil Johnnie,' as he was nicknamed; the adopted son of a poor widow in Venango County, Pennsylvania, upon whose farm the valuable grease was found by the thousands of barrels; and unfortunately she died without being able to finish her peculiar son's education. Being only twenty years old at the time of coming into his inheritance, he proceeded to sow the wind most luxuriously; and it was less than five years before he was putting in his valuable time in reaping the whirlwind. He squandered thousands of dollars a day, hired ballet dancers, gave suppers costing thousands of dollars and with the most unheard-of courses; raced at night from one brothel and gambling den to another as fast as his feet could carry him. He used to walk the streets with bunches of greenbacks in the buttonholes of his coat. Some were blown out by the wind, many were snatched from his person as he walked unconcernedly along; now and then, for the sake of variety, he plucked others from his pockets and threw them off into space, to the speechless delight of bootblacks, street sweepers, laborers, policemen, servant girls, and all nations, ages, sexes, and colors. Even the dogs followed him with longing eyes. Thousands of attempts were made to reach his pockets. The slightest appeal for aid, whether deserving or not, was responded to with a generosity that fairly took away the breath of the applicant; sharpers followed at his heels whenever he appeared on the streets, and thrust their presence upon him at every corner; he once took a fancy to a certain minstrel troupe and purchased for them an outfit which fairly blazed with costly decorations and ornaments.

"On one occasion he went into a hotel where the clerk and his aids failed to recognize his importance and treated him coolly. Angered, he pulled out from some concealed corner of his rather

disreputable-looking person a roll of greenbacks and demanded the price of the house including servants and fixtures. The bewildered proprietor, for whom the frightened clerk at the desk promptly sent, thinking he was dealing with a maniac, named a price; and 'Johnnie' laid down the price on the desk, and promptly ordered the offending clerk and a porter or two who had offended him to 'dust and be lively about it.' He then took possession and indulged with a few of his chosen comrades, for a day or so, in some of the wildest and most ridiculous exploits of eating, drinking, sleeping, and carousing that the world has ever heard of, and then presented the house to a clerk who struck his fancy.

"But he could not like Tennyson's brook 'go on forever'; for after a few years of this rapid living, Mr. John W. Steele, teamster, as he was originally known, was glad to accept the position of door-keeper to the very minstrel troupe which in his halcyon days he had so generously fitted out with a golden equipment."

Storage and Transportation of Oil. Ordinarily, each well has a tank of its own with a capacity of 250 barrels connected with the well by a 2-inch pipe. A larger pipe connects this tank with one of perhaps 10,000 barrels capacity. Pipe lines made of lengths of wrought iron pipe, capable of withstanding a pressure of 2000 pounds per square inch, screw into collars and form a continuous line, often reaching hundreds of miles. These lines connect the oil fields with the cities of Cincinnati, Cleveland, Chicago, Buffalo, New York, Jersey City, Philadelphia, and Baltimore. Enormous iron tanks capable of holding 40,000 barrels are placed at intervals along such lines and the oil forced by powerful pumps through forests, over mountains, across valleys, under rivers, from station to station across the continent.

Pumping stations are from 25 to 30 miles apart and consist of a boiler house of brick, with large tubular boilers of 80 or 100 horse

power, and great pumps that can force 25,000 barrels a day through three 16-inch pipes from one station to the next.

Petroleum is rich in paraffin, which has a tendency to adhere to the pipes and clog them. To remove this a clever piece of mechanism called a *go-devil* is used. It is hinged with a ball and socket joint that allows it to follow any of the bends in the pipes, and fitted with steel knives on a spindle that are caused to turn as the oil passes through. As the go-devil is forced forward, the knives revolve and scrape away the obstructions.

For the European trade especially constructed oil tank steamers, costing half a million dollars each and with a carrying capacity of 2,700,000 gallons of oil, are used.

The striking of storage tanks by lightning is not uncommon, for the large masses of metal with the ascending columns of light, warm gas form excellent conductors of electricity, and a huge oil tank in flames presents a sight never to be forgotten. In the case of a burning tank, cannon kept in reserve are brought out, the tank pierced by shot and the oil diverted into streams near by and run off.

The United Pipe Line Association now owns more than 3000 miles of pipe, iron tanks with a capacity of more than 35,000,000 barrels, and over 100 pumping stations, a remarkable contrast with the first efforts to gather the oil when tanks, barrels, boxes, bottles, cans, pans, and even old hats were used, and the liquid wealth carried by hand or hauled about by ox teams. Mules, horses, or camels with buckets or tubs are still used to some extent for the transportation of oil in the Caspian district. An elaborate system of bookkeeping and accounting enables the transportation companies to receive into the line the oil of hundreds of producers.

If a producer wishes to draw off 100 or 200 barrels into one of the great storage tanks in the valley he signals the gauger in the service of the storage company, who measures the height of the oil

in the great tank, then the valves are thrown open, the oil from the well is received until the flow ceases. Another measurement of the height of oil in the receiving tank is taken and the difference between the two levels accurately determined to within a minute fraction of a barrel and placed to the credit of the producer, who receives a certificate from the storage company. The certificates can be deposited in a bank like checks or negotiated like any form of business paper, can be used as collateral security, are subject to transfer by indorsement, and form an important factor in banking, commerce, and oil trade circles.

Our debt to petroleum is greater than appears at first thought, for kerosene is the light depended upon in country homes and small villages where gas plants and electric lights are not available. The difference between the light furnished by tallow candles or smoky, ill-smelling whale oil lamps and the light of a "Rochester burner," using kerosene oil, needs only to be seen to be fully appreciated. Good artificial light not only saves the sight and prolongs the hours for work or amusement, but it has also prevented suffering and loss of life, for the petroleum industry practically put out of business the whale fishery with its attendant train of privations, wrecks, and losses of life. The whales had been so diminished in number that whalers were compelled to make long voyages to the Arctic, where frequently frozen in the ice they remained through the long dreary Arctic winter, their crew suffering untold privations from the lack of suitable food, then scurvy with its awful ravages appeared, boats were often overturned by angry whales, and vessels were caught in ice floes. Such were a few of the horrors and a part of the price that was paid for the whale oil lamp. The by-products of petroleum are so numerous that a single volume could hardly do them complete justice; but vaseline, paraffin, asphaltum, lubricating oils, and gasoline are the best known.

The Wells light is a very simple apparatus for using the vapor of kerosene, and is remarkably efficient. It consists of a steel tank of a size that can be easily handled and the burner connected with the tank by an iron tube. A valve in the connecting tube is closed and the tank pumped about two thirds full of kerosene. This compresses the air within the tank and gives a pressure of 25 pounds or more. The burner is then heated and the valve in the connecting tube opened. The pressure within forces a fine stream of kerosene through a series of tubes arranged in spiral form and heated so hot that by the time it reaches the end of the spiral, the kerosene is not only vaporized, but made into a gas, when it ignites and burns under high pressure, forming a long, solid flame which gives out great light and heat. An 800 candle power light can be obtained by the use of half a gallon of kerosene per hour, and if the kerosene be increased to 1½ gallons per hour, 4000 candle power can be developed. The whole apparatus is easily moved about and is well adapted for many kinds of mining, excavating, and factory illumination, as the size of the flame can be varied at will. It possesses such great heating power that by its aid locomotive tires can be set without removing the trucks from the engine frame. The lamp has made possible the working of forces of men in the open air where other forms of light are not suitable or available.

The Standard Oil Company. A few words concerning the oldest and strongest combination of capital and brains that the American continent has seen outside of railroad operations may not be out of place. The history of the Standard Oil Company is so interwoven with that of the petroleum industry that one cannot be followed without taking some notice of the other. Mr. Carnegie says, "The only people who have reason to fear trusts are those who trust them." The late Lord Chief Justice Russell of England said that in seven years the losses to the public through failures of trusts had

been "no less a sum than £28,159,482 ($136,855,082), made up of losses of creditors dealing with such companies, £7,696,848 ($37,406,681), and of loss to the wretched contributors or shareholders £20,462,634 ($99,448,401), and when we recollect that these are the figures relating only to companies wound up compulsorily and that they exclude cases of reduced capital and losses in relation to companies whose present value represents a very few shillings or pence in the pound of their par value, you will see that the loss to the public is enormous."

But the Standard Oil Company has been managed with such conspicuous ability that it has avoided all the shoals and rocks upon which others have foundered and is the accepted standard from which arguments in support of the trust idea are usually drawn. It has been attacked often and furiously by the press and the pulpit, blackmailed by state legislators and legal functionaries, and so much has been said and written both in abuse and praise of it that it is small wonder if the average citizen looks upon it with distrust or even fear. But persons whose minds are trained in economic thought and who hold that man is not totally depraved find it hard to believe that such a matchless organization can be founded solely upon a basis of bribery and corruption.

Mr. Rockefeller was summoned before a congressional commission appointed to investigate the trust problem, and given a series of questions to which he replied in writing. The following is his answer to the question as to what induced the first combination of firms in the oil business.

Testimony of John D. Rockefeller. "The desire to unite our skill and capital in order to carry on a business of some magnitude and importance in place of the small business that each separately had theretofore carried on.

"As the business grew and markets were obtained at home and

abroad, more persons and capital were added to the business and new corporate agencies were obtained or organized, the object being always the same — to extend our business by furnishing the best and cheapest product.

"I ascribe the success of the Standard to its consistent policy to make the volume of its business large through the merits and cheapness of its products. It has spared no expense in finding, securing, and utilizing the best and cheapest methods of manufacture. It has sought for the best superintendents and workmen, and paid the best wages. It has not hesitated to sacrifice old machinery and old plants for new and better ones. It has placed its manufactories at the points where they could supply markets at the least expense. It has not only sought markets for its principal products, but for all possible by-products, sparing no expense in introducing them to the public. It has not hesitated to invest millions of dollars in methods for cheapening the gathering and distribution of oils, by pipe lines, special cars, tank steamers, and tank wagons. It has erected tank stations at every important railroad station to cheapen the storage and delivery of its products. It has spared no expense in forcing its products into the markets of the world, among people civilized and uncivilized. It has had faith in American oil, and has brought together millions of money for the purpose of making it what it was, and holding its markets against the competition of Russia and all the many countries which are producers of oil and competitors against American oil."

Advantages of Combining. "Much that one man cannot do alone two can do together, and once admit the fact that co-operation, or, what is the same thing, combination, is necessary on a small scale, the limit depends solely upon the necessities of business. Two persons in partnership may be a sufficiently large combination for a small business, but if the business grows or can be made to grow,

more persons and more capital must be taken in. The business may grow so large that a partnership ceases to be a proper instrumentality for its purposes, and then a corporation becomes a necessity. In most countries, as in England, this form of industrial combination is sufficient for a business co-extensive with the parent country, but it is not so in this country. Our Federal form of government, making every corporation created by a state foreign to every other state, renders it necessary for persons doing business through corporate agency to organize corporations in some or many of the different states in which their business is located. Instead of doing business through the agency of one corporation, they must do business through the agencies of several corporations. If the business is extended to foreign countries — and Americans are not to-day satisfied with home markets alone — it will be found helpful and possibly necessary to organize corporations in such countries, for Europeans are prejudiced against foreign corporations, as are the people of many of our states. These different corporations thus become co-operating agencies in the same business, and are held together by common ownership of their stock.

"It is too late to argue about advantages of industrial combinations. They are a necessity. And if Americans are to have the privilege of extending their business in all the States of the Union and into foreign countries as well, they are a necessity on a large scale and require the agency of more than one corporation. Their chief advantages are: —

"1. Command of necessary capital.

"2. Extension of limits of business.

"3. Increase of number of persons interested in the business.

"4. Economy in business.

"5. Improvements and economies which are derived from knowledge of many interested persons of wide experience.

"6. Power to give the public improved products at less prices and still make profit for stockholders.

"7. Permanent work and good wages for laborers.

"I speak from my experience in the business, with which I have been intimately connected for about forty years."

Pipe Lines. "We soon discovered as the business grew that the primary method of transporting oil in barrels could not last. The package often costs more than the contents, and the forests of the country were not sufficient to supply the material for an extended length of time. Hence we devoted attention to other methods of transportation, adopted the pipe line system and found capital for pipe line construction equal to the necessities of the business. To operate pipe lines required franchises from states in which they were located, and consequently corporations in those states, just as railroads running through different states are forced to operate under separate charters. To perfect the pipe line system of transportation required in the neighborhood of $50,000,000 of capital. This could not be obtained or maintained without industrial combination.

"The entire oil business is dependent upon this pipe line system. Without it every well would be shut down, every foreign market would be closed to us. The pipe line system required other improvements, such as tank cars upon railways, and finally the tank steamer. Capital had to be furnished for them, and corporations created to own and operate them. Every step taken was necessary in the business if it was to be properly developed.

"The dangers are that the power conferred by combinations may be abused, that combinations may be formed for speculation in stocks rather than for conducting business, and that for this purpose prices may be temporarily raised instead of being lowered.

"These abuses are possible to a greater or less extent in all combinations, large or small, but this fact is no more of an argument

against combinations than the fact that steam may explode is an argument against steam. Steam is necessary and can be made comparatively safe. Combination is necessary, and its abuses can be minimized; otherwise our legislators must acknowledge their incapacity to deal with the most important instrument of industry.

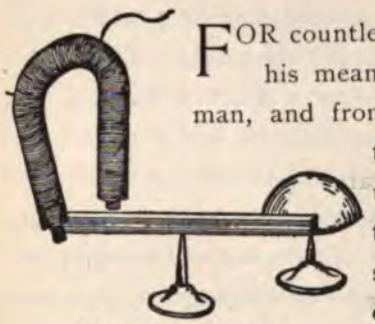
"Hitherto most legislative attempts have been an effort not to control, but to destroy, hence their futility."

CRIPPLE CREEK.

MEANS OF COMMUNICATION.

Electric Telegraph — Heliograph — Contributions of Morse — First Telegraph Line in America — Wireless Telegraphy — Submarine Cables — Uses of Cables — Telephone — Wireless Telephony — Phonograph — Telautograph — Moving Picture Machines — Postal Service — Canadian System — Postal Union — Free Delivery — Pneumatic Tube Postal Service — Trans-continental Mails — Pony Express — Two-cent Rate to the Philippines.

ELECTRIC TELEGRAPH.



HENRY'S TELEGRAPH.

FOR countless centuries man has striven to quicken his means of communication with his fellow-man, and from time immemorial has employed for that purpose sight and sound, but the use of electricity is the gift of the nineteenth century. The fleet-footed messengers and the couriers in relays so often mentioned in Greek history, the fiery cross which Sir Walter Scott describes in his "Lady of the Lake," war drums, trumpets, and alarm bells, all were used. Light is immensely superior to sound in speed, and signal beacons burning on mountain tops were used so early that tradition says that when ancient Troy fell, in the eleventh century B. C., Agamemnon conveyed the news to Clytemnestra, his wife, by a chain of signal beacons stretching from Mount Ida to the palace of the queen.

The semaphore, the first really efficient telegraph, was invented by Claude Chappé and adopted by the French government in 1794. As adopted, it consisted of a vertical post with a movable arm to which were attached two smaller pivoted arms. By different movements of these arms 98 distinct signals could be made. The system

was soon in general use throughout Europe and nearly every nation had its semaphores placed on towers 4 or 5 miles apart forming long lines. Nicholas I. of Russia constructed one at an expense of millions of dollars, with 220 stations, running from the Austrian frontier to St. Petersburg.

The heliograph is a system of conveying signals by the use of flashes of sunlight from mirrors. Its use in South Africa during the heroic siege of Ladysmith has rendered the term familiar. Messages can be sent in this way for a surprisingly long distance. The French have employed it between the islands of Mauritius and Reunion in the Indian Ocean, the stations being on mountain tops 133 miles apart. The United States Signal Corps on the top of Mount Uncompahgre, Colorado, has communicated with Mount Ellen in Utah, 183 miles away. The British navy uses calcium and electric lights for similar purposes, and at the siege of Paris calcium lights aided by lenses and reflectors were frequently employed to send messages from one station to another 20 miles or more away. The army and navy of all civilized nations are now able to telegraph by means of flash lights and signal flags.

As soon as it became known that electricity could be transmitted for a considerable distance through a conductor, various attempts were made to utilize it for telegraphic purposes. What is generally accepted as the earliest suggestion of this kind appeared in *Scott's Magazine*, February 1st, 1753, in which the writer proposes to employ as many wires as the letters of the alphabet, having at the end of each wire a letter and a suspended pith ball. The ball would move when a current of electricity was sent through the wire and signal the letter to be employed, and words were to be spelled out in this way. It is to be regretted that the author of the first practical suggestion of an electrical telegraph has never been identified.

Claims of Morse. The name of Samuel F. B. Morse seems to

many people to stand for everything connected with the modern telegraph. Great credit is due Morse for the energy, the will power, and remarkable perseverance he displayed in securing recognition and adoption for the telegraph, but he had very little part in the construction of what constitutes the electric telegraph of to-day. The first electric telegraph ever constructed was that of Le Sage at Geneva, Switzerland, in 1774. He used 24 wires, each named after a letter of the alphabet and fitted with an electroscope which moved when an electric impulse was sent through the wire. In 1796 Salva in Spain worked by static electricity a line 26 miles long. Soemering of Munich operated a telegraph in 1807, using Volta's cells, and published accounts of it in scientific journals and exhibited it to learned societies. In England Sir Francis Ronalds had in 1816 a line 8 miles long, the wire of which was suspended on silken strings. When he tried to interest the British government he received the reply, "Telegraphs of any kind are now wholly unnecessary and no other than the one now in use will be adopted." All these were imperfect and expensive machines, and it was not until after the discoveries of four great men that the modern telegraph became possible.

Essential Parts of the Telegraph. In the electric telegraph of to-day there are four things necessary: the battery, the conducting wire, the electro-magnet, and the instruments for sending and receiving messages. The battery was made possible by the discoveries of Galvani and Volta, which have been described, and made practicable by the Daniell cell. It had been known for some time that currents of electricity could be sent through considerable lengths of wire, and Weber discovered in 1823 that he could pass an electric current through a copper wire carried over the houses and steeples of Göttingen without insulating it. For the electro-magnet, the work of four men was required: Oersted (Danish), who in 1819

first detected the effect of the electric current on a magnetic needle; Arago (French), who in 1820 discovered that the current could generate magnetism; Sturgeon (English), who produced the first electro-magnet; and Henry (American), who was the first to operate an electro-magnet at a distance. Barlow, an eminent English scientist, had tried in 1824 to apply Sturgeon's magnet to the telegraph but failed because, as he says, "I found such a sensible diminution with only 200 feet of wire as at once convinced me of the impracticability of the scheme," and the only practical application made of the discovery of Oersted was the use of a magnetic needle deflected at will to the right or the left by an electric current. By the use of a code signals could be sent.

Prominent Experimentalists. Gauss and Weber in 1833 set up such a telegraph at Göttingen. Cooke, who afterward became famous for his connection with the needle telegraph, applied in 1837 to Faraday for information that would help him to work an electro-magnet at a distance. Faraday referred him to Wheatstone, who pronounced his plan impracticable. In 1837 Cooke and Wheatstone took out an English patent for an electric telegraph by which signals were given by electric needles. It is difficult in these days of instantaneous communication to realize how little nations knew of each other three fourths of a century ago, for six years *before* Wheatstone had pronounced the electro-magnet impracticable, Professor Joseph Henry of the Albany Academy strung more than a mile of wire about the walls of that building and set up an electro-magnetic telegraph which he describes as follows: "I arranged, around one of the upper rooms in the Albany Academy, a wire of more than a mile in length, through which I was enabled to make signals by sounding a bell. The mechanical arrangement for effecting this object was simply a steel bar, permanently magnetized, of about ten inches in length, supported on a pivot, and placed with its north end between

the two arms of a horseshoe magnet. When the latter was excited by the current, the end of the bar, thus placed, was attracted by one arm of the horseshoe and repelled by the other, and was thus caused to move in a horizontal plane, and its farther extremity to strike a bell suitably adjusted." This was the first *sounding* telegraph in the world.

"In 1835 Professor Henry, who had been called to Princeton College, constructed a line and worked it as it is to-day worked, with a relay and local circuit, so that at that period all the problems had been worked out. But, like the speaking telephone in its early inception, no one appreciated its real importance. Henry himself did not think it worth while to take out a patent."*

Wheatstone and Cooke were knighted by Queen Victoria for the invention of an electric telegraph that has been superseded by that outlined years before by Henry. Henry's Princeton line in the Philosophic Hall used one wire, one end of which terminated in the well at his home and the other in the earth at his laboratory in the college buildings. It was not until 1837 that Steinheil at Munich worked his electric telegraph by a single wire, using the earth as part of a circuit. We will allow Professor Henry to speak for himself. "At the time of making my original experiments in electro-magnetism in Albany I was urged by a friend to take out a patent both for its application to machinery and to the telegraph; but this I declined on the ground that I did not then consider it compatible with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual."†

Contributions of Morse. In 1832 Morse began work on the electric telegraph, and in 1837 exhibited a line at the University of the City of New York in Washington square, by which signals were sent

*Prof. Elisha Gray.

† "Joseph Henry and the Magnetic Telegraph." Edward N. Dickerson.

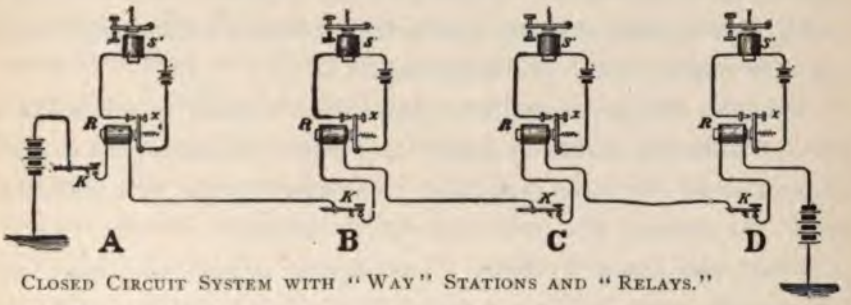
by electricity. He was aided in this work by Professor John W. Draper. Morse had interested Judge Stephen Vail of Speedwell, New Jersey, who furnished the money for the enterprise and whose son, Alfred Vail, assisted Morse in his work, and for whom a large share of the credit has been claimed. The code called by Morse's name is said to have been invented by young Vail from suggestions given him by printers as to the order in which the letters of the alphabet were most used. In 1843 Congress made an appropriation of $30,000 to build an experimental line for Morse between Baltimore and Washington, and over this line was sent the famous message, "What hath God wrought."*

The first telegraphic line in America was thrown open to the public April 1, 1844. The tariff was one cent for four words. "During the first four days the receipts amounted to one cent. This was obtained from an office seeker, who said that he had nothing else than a twenty-dollar bill and one cent, and, with the modesty of his class, wanted to see the operation free. This was refused because against orders. He was then told that he could have a cent's worth of telegraphy, to which he agreed. He was gratified in the following manner: Washington asked Baltimore, '4?' which meant in the list of signals, 'What time is it?' Baltimore replied, '1,' which meant, 'one o'clock.' This was one character each way, which, according to the tariff, would amount to half a cent. The man paid his one cent, declined the change, and went his way. This was the revenue for four days. On the fifth 12½ cents were received. The sixth was the Sabbath. On the seventh the revenue ran up to 60 cents; on the eighth, $1.32. On the ninth they were 1.04."†. This is an

*The code known as the Morse code is as follows. A .— B —... C —.—. D —.. E . F ..—. G ——. H .... I .. J .——— K —.— L .—.. M —— N —. O ——— P .——. Q ——.— R .—. S ... T — U ..— V ...— W .—— X —..— Y —.—— Z ——.. & .—... 1 .———— 2 ..——— 3 ...—— 4 ....— 5 ..... 6 —.... 7 ——... 8 ———.. 9 ————. 0 —————

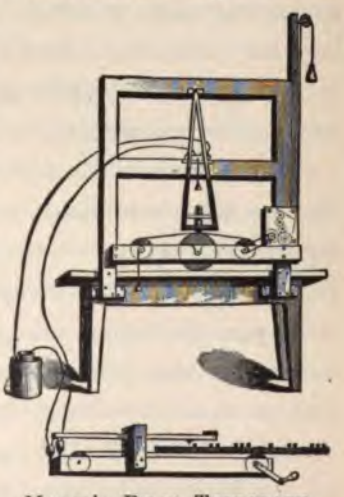
†James D. Reid, "The Telegraph in America."

interesting commentary on the progress of the time, for numerous wires and dozens of offices are now required to conduct the telegraphic business between these two cities.



CLOSED CIRCUIT SYSTEM WITH "WAY" STATIONS AND "RELAYS."

The working of a Morse telegraph is simple when understood. Suppose a properly insulated wire to connect Ottawa with Washington, each end being connected with the earth and forming a circuit as shown in the figure herewith. When the keys at both ends are closed the batteries are in action and the electro-magnets attract the armatures or keepers. If either key is opened the current stops, the electro-magnets no longer attract the armatures, which are drawn away by a spring, giving forth a click that conveys an intelligible sound to the operator.



MORSE'S FIRST TELEGRAPH INSTRUMENT.

Relays and repeaters are used because it is difficult to send an electric current through so long a line, 400 miles for iron wire being about the limit. Suppose a relay station established at Toronto; the electric impulse arrives there like a courier, out of breath and exhausted, but has sufficient strength to operate a battery there, which

sounds out the message distinctly and hurries forward the signal to another relay station that may be located at Buffalo, that in turn forwards it to New York or Philadelphia, thence on its way to Washington. It is the weak current's ability to close the circuit of a strong battery and wake up and set in motion a fresh courier that gives the name "relay" to the system.

The first Morse telegraphs employed a register which made a series of dots and dashes on paper from which the message was read, but gradually the operators came to be able to read by sound, and that is the method now most used the world over.

Other and Later Systems. The needle system of Cooke and Wheatstone, used in England before Morse had prevailed upon Congress to build his experimental line, was soon followed by the chemical telegraph of Bain, the printing telegraph of House, and later that of Hughes. But they are all too complicated to be described within the space to which this article is limited, and although printing and automatic systems are used in America to some extent the greater part of the work is done by sound writing and copied either by hand or typewritten.

Morse counted himself happy to be able to get one message over the line at a time, but soon half a dozen inventors were trying to increase the capacity of the line for work, although it was not until 1872 that Joseph B. Stearns of Boston invented a condenser which made possible duplex telegraphy. Now it is possible to use the same wire at the same time for carrying many messages in both directions, without their interfering with each other in the least. The apparatus by which this is effected represents the combined effort of the greatest minds of electrical science. The time required to transmit an electrical signal over an ordinary line is less than 1-500000 of a second, and the human mind and hand cannot approach such speed, hence the signals do not interfere with each other.

Edison developed and put in operation about 1878 a quadruplex system by which four messages could be sent over the same wire at the same time. This, of course, immensely increased the capacity of the wire to do business and is said to have added $15,000,000 to the value of the Western Union Telegraph Company alone. Other methods employ something like a typewriter that punches holes in a paper tape. When a series of messages have been thus prepared the tape is run through a machine having electrical connection with a telegraph line, and metal points or brushes drop into the holes and transmit an electrical impulse that at another office signals the letters which the holes in the tape represent. With this or a similar system it has been found possible to transmit more than 1000 words a minute over a line.

Printing Telegraph. Royal C. House invented in 1846 a printing telegraph, by which the message was printed on a slip of paper. This has been perfected and developed until to-day it is represented in the broker's office by a "ticker" on which is printed automatically the market quotations of different securities.

The Pollak-Virag system of multiplex telegraphy calls photography to its aid. To put the message in sending form, a paper tape is run through a machine which is perforated in two lines, the upper line for the dashes, the lower line for the dots of the Morse code. The tape when prepared is run rapidly over a wheel electrically connected with the telegraph line. Pressing upon the tape are two small brushes, one for the dash line and one for the dot line. The first is connected with the positive pole of a battery and the second with the negative. The only limits to the number of words that can be sent are the speed with which the wheel can be turned and the number of signals that can be sent over the wire without confusion, but the speed of the wheel is only a question of power and gearing and the number of signals is practically unlimited,

for as many as 500,000 distinct signals can be sent each second. At the receiving station is a mirror galvanometer upon which the light from a small incandescent lamp falls. The mirror turns and throws the rays in one direction for dots and in the other for dashes. The rays, brought to a point by a convex lens and falling on a rapidly moving sensitized paper ribbon, are there photographed. The sensitized paper can be developed in four minutes and the message read as though it were a cable message. In a test at Berlin before representatives of the Hungarian, French, and American government 220 words were transmitted in 9 seconds, and 122,000 words per minute have been transmitted by this system between Chicago and Buffalo.

Telegraphing to Moving Trains. As we have seen in the study of the dynamo, at the instant of the starting or stopping of an electric current a secondary impulse is set up. The same thing occurs whenever a current passes through a telegraph wire, and this impulse is communicated to objects near by and from them passes to the earth. Edison employed the metallic roofs of cars to receive this induced current from the wire. A battery placed in a moving car has within its circuit an intensifying coil, a "buzzer," and a telephone receiver. As the induction impulse occurs only with the making and breaking of a telegraphic current it cannot be used for the Morse code, so the impulses are gathered into a "buzzer" and read by a telephone instead of the Morse register. This had several successful trials before it was installed for a time on the Lehigh Valley railroad, but as there was not much demand for it commercially it was withdrawn. However, it is practicable and awaits only the call for its services.

Wireless telegraphy is now an accomplished fact and many able electricians have contributed to bring it about. In 1864 Clerk Maxwell declared that electricity and light differed only in the length of the waves (those of light being the longer) having the same velocity,

186,400 miles per second. Heinrich Hertz, a German scientist, in 1888 proved the truth of Maxwell's theories and showed that alternating currents of high frequency in an open circuit could be conveyed away from the circuit as electric waves. He further demonstrated that waves of electricity can be reflected and refracted like waves of light and that at a certain intensity air became a good conductor.

The coherer made the practical application of "Hertzian waves" possible. Varley in 1866 noticed that the dust of black lead sprinkled between the poles of a battery intercepted the current, but when the current was made powerful enough, the black lead dust became compact and formed an excellent conductor. Onesti in 1885 observed the same phenomenon in powdered copper, and in 1891 Branley of Paris brought out a coherer in which this principle was applied and he also discovered that the conductivity of the particles could be destroyed by shaking or tapping them. Dr. Lodge of London added to the knowledge in 1894, and in 1899 Marconi, an Italian residing in England, successfully established communication across the English Channel, 32 miles, since which time the range of the system has been extended to about 100 miles.

The improved coherer is a glass tube about 1½ inches long and 1-12 of an inch internal diameter. Within this are two silver electrodes which fit the tube and approach within a minute fraction of an inch of each other. The space between the electrodes is filled with fine nickel and silver filings, the merest trace of mercury, and the air within the space exhausted to within 1-100000 part.

It is operated as follows: A powerful battery with an induction coil sends a current to two brass spheres about three inches in diameter nearly touching each other. A spark leaps from one sphere to the other and sends out waves which travel through the atmosphere and act upon the coherer at a distance, causing the fine filings be-

tween the electrodes to become compact and furnish a good conductor of electricity. The electrodes are part of a local battery, the current of which has been waiting for the space between the poles within the glass tube to be bridged so that it can pass. When an electric impulse from the brass balls passing through the air acts upon the dust between the poles of the coherer and converts it into a good conductor, a circuit is established in the local battery, which, by connecting with a relay, can be made to sound a signal like an ordinary telegraph receiver.

In the Marconi coherer a little hammer is made to fall with a slight tap upon the glass tube and at the jar the particles of dust fall apart ready to be again acted upon by the electric impulse from afar. Such an impulse, almost too feeble to be computed, is sufficient to change the filings between the poles from a barrier to a conductor of electricity that will furnish passage for the waiting current of the local battery. In actual service the waves are caught by a single wire or a network of wires insulated and raised vertically above the ground on a tall mast, the greater the height the greater the distance from which signals can be received. The waves, when caught, cause electrical vibrations to be carried down the mast to the coherer. The transmitters and receivers can be so delicately adjusted or "attuned" to each other that the receiver will take messages only from its own transmitter, and thus absolute privacy can be secured. The energy of a Marconi sending apparatus is sufficient to produce an arc light of 1000 candle power, and sensitive as is the coherer to influences almost immeasurable, it cannot compare in its delicacy with the human eye.

Advantages of Marconi System. The Marconi system of wireless telegraphy can never become a successful competitor with present commercial methods because only fifteen words a minute can be transmitted by it. But it has great possibilities in other lines. The

ships of a squadron equipped with it might in the night run past threatening batteries and communicate with each other without displaying any telltale signals that would draw the fire of the enemy. Crowded ocean passenger steamers equipped with such an apparatus could communicate with lighthouses or signal stations located on dangerous reefs even through the fog and the darkness. A well equipped Marconi system would have allowed the besieged ministers at Pekin to communicate with the relief force at Tien-Tsin, and would have thus relieved much of the anxiety that prevailed during that period of mystery and fear.

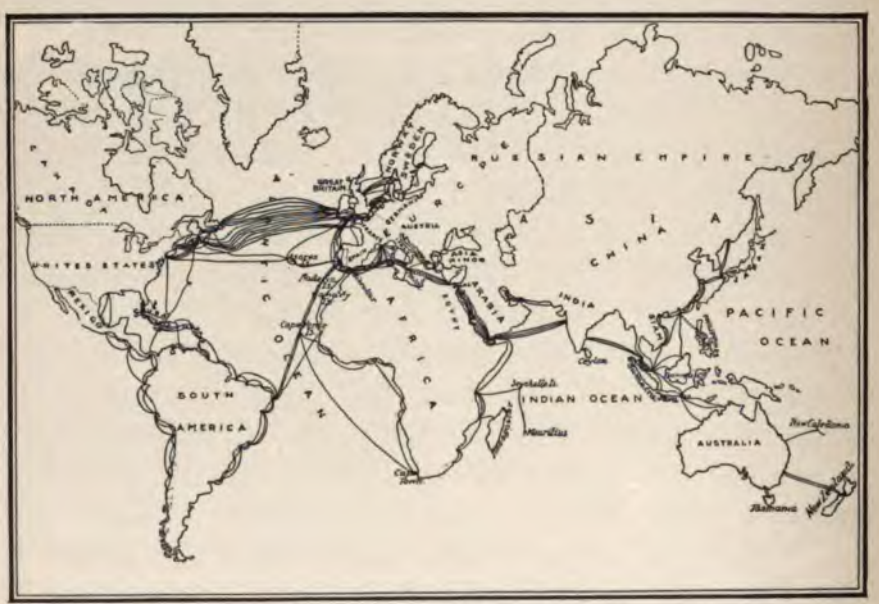
Humanitarian and Utilitarian Aspects of the Telegraph. If the canals, railroads, and steamship lines are the muscles of a nation, the telegraph may not inaptly be styled its nervous system. It has annihilated distance and practically enables a man to make his voice heard at the uttermost ends of the earth. It alleviates human suffering by calling the physician or surgeon to the bedside, or by hurrying aid to an accident or a great disaster like that at Galveston. It makes possible far-reaching commercial transactions. It is invaluable in directing the operations of any large organization, military or otherwise. It deters from some crime by the knowledge that windows, doors, and safes may be guarded by burglar alarms, and it enables the forces of law and order to communicate so quickly and freely as to render the escape of a criminal almost impossible. A general in the wilds of Africa found he must have a bridge to cross a river before the rainy season opened and the stream rose. By means of the electric telegraph he communicated with the leading manufacturers of Europe and America and the bridge was ordered, constructed, and placed on board a vessel in New York harbor ready for shipment in less time than would have been required to send and receive an answer by mail.

It is impossible for society to estimate the value of the telegraph's

contributions to human happiness and comfort or the saving effected in time and labor. The close of the century saw (exclusive of the ocean cables) more than 100,000 telegraph offices, 3,000,000 miles of telegraph wire, and 365,000,000 messages sent annually.

SUBMARINE CABLES.

Beneath the bosom of the North Atlantic lie fourteen submarine cables that throb with the messages of the Old World and the New.



CABLE MAP OF THE WORLD.

Three cables underlie the South Atlantic, connecting South America with Europe and Africa, and numerous others connect Great Britain with her Indian, African, and Australasian possessions. It lacks but a solitary cable across the Pacific to girdle the globe, and the demand for it is so great that it will soon be forthcoming, either as the "All British Cable" or an American cable connecting Hawaii, Guam, and the Philippines.

Although no longer ago than 1866 the first permanently successful transatlantic cable was completed, there are now no less than 1500 distinct sections of submarine telegraphs with an aggregate length of about 180,000 miles and estimated to have cost $250,000,000.

Early Experiments. It is impossible to determine who first broached the subject of submarine cables and there are many claimants for that honor. Certain it is that a submarine cable was laid by Captain J. B. Sleeth under the Ohio river to Paducah, Kentucky, in 1845. This cable was an iron wire wrapped with strips of canvas soaked in pitch. It worked well for a time but the insulation was affected by the water and electric losses became so great that it was rendered useless. Cyrus W. Field offered Captain Sleeth financial backing in experiments relating to insulation, but the offer was declined and the cable not patented.

The same year that Captain Sleeth laid his cable Messrs. John and Jacob Brett laid before the British Government a plan for a cable connecting Europe and America, but the spirit that had refused recognition to Sir Francis Ronalds's electric telegraph a generation before still prevailed and pronounced this plan wholly impracticable and disdainfully rejected it.

Atmospheric air, under ordinary conditions, is not a good conductor of electricity, and telegraph wires suspended above the earth need insulation only at points of contact, but when carried under water insulation is necessary and this was the greatest problem to be solved before submarine cables of great length could be laid. In 1847 gutta percha was brought to the notice of the electrician and soon adopted as an insulator

In 1850 the English Channel was vanquished by a cable 25 miles in length connecting Dover and Calais. It was a single wire covered with gutta percha but it was too weak to stand the strain and soon broke. A year later a second cable composed of four copper wires

each insulated with gutta percha reinforced by ten iron wires was laid, worked successfully, and has furnished the model for all subsequent cables of that character.

Transatlantic Cable. In 1854 Cyrus W. Field, to whose indomitable energy, personal magnetism, and courage every submarine transatlantic cable is a monument, determined to form a company to connect Valentia, Ireland, with Heart's Content, Newfoundland, a distance of a little more than 1600 miles. To his enthusiasm and great common sense Mr. Field united a high reputation as a financier. He employed eminent electricians who, through courtesies shown, were able to unite for experimental purposes various lines laid over land and under water aggregating about 2000 miles, and proved that through a distance greater than across the Atlantic four signals a second could be sent. The Atlantic Telegraph Company was organized December 9, 1856, with a capital of $1,750,000, and in 1857 a cable was manufactured. The British and American governments, which had given some financial aid, loaned the battle ships *Agamemnon* and *Niagara* to aid in laying the cable. The *Niagara* sailed from Ireland, but when she had steamed westward 360 miles a sudden strain on the paying machinery caused the cable to snap, and, to the great dismay of all on board, $500,000 worth of cable vanished from sight and lay in the bottom of the Atlantic at a depth of over two miles. The ships returned to Valentia with flags at half-mast. Not discouraged, Field secured money for a new attempt, more cable

CYRUS W. FIELD.

was made, and in May, 1858, 3000 statute miles of cable was divided in halves and coiled in the holds of H. M. S. *Agamemnon* and the U. S. S. *Niagara*. The two grandest battle ships of the time met in mid-ocean June 25, 1858, and on June 26 the cable was spliced and three miles paid out when an accident occurred to the machinery of the *Niagara* and the cable broke. A new splice was made and 40 miles was paid out when another break occurred. A third splice was made with the agreement that if more than 100 miles was paid before another break occurred both ships should return to Valentia; 200 miles was paid out and hopes were running high when a break occurred 20 feet from the stern of the *Agamemnon*. The ships met at Valentia. Still undiscouraged, Field secured a new supply of cable, recoaled the ships and again started on his mission. July 29 a new splice was made in mid-ocean, and as the cable was paid out signals were constantly sent from ship to ship by means of the cable, and on the morning of August 5, 1858, the ends were landed at opposite sides of the Atlantic, the European terminus in Trinity Bay, Valentia, Ireland, and the American terminus in Bull's Arm, Trinity Bay, Newfoundland. On August 16, 1858, at 11.12 A. M., the first message was transmitted. It was as follows:—

"Directors Atlantic Telegraph Co., Great Britain, to Directors in America.—Europe and America are united by telegraph. Glory to God in the highest; on earth peace, good will toward men."

Then followed a message from Queen Victoria to President Buchanan.

"To the President of the United States, Washington: —

"The Queen desires to congratulate the President upon the successful completion of this great international work, in which the Queen has taken the deepest interest.

"The Queen is convinced that the President will join with her in fervently hoping that the Electric Cable which now connects Great Britain with

the United States will prove an additional link between the nations whose friendship is founded upon their common interest and reciprocal esteem.

"The Queen has much pleasure in thus communicating with the President, and renewing to him her wishes for the prosperity of the United States."

The President replied,

"Washington City, Aug. 16, 1858.

"To Her Majesty, Victoria, Queen of Great Britain :—

"The President cordially reciprocates the congratulations of Her Majesty, the Queen, on the success of the great international enterprise accomplished by the science, skill, and indomitable energy of the two countries. It is a triumph more glorious, because far more useful to mankind, than was ever won by conqueror on the field of battle.

"May the Atlantic Telegraph, under the blessing of Heaven, prove to be a bond of perpetual peace and friendship between the kindred nations, and an instrument destined by Divine Providence to diffuse religion, civilization, liberty, and law throughout the world. In this view will not all nations of Christendom spontaneously unite in the declaration that it shall be forever neutral, and that its communications shall be held sacred in passing to their places of destination, even in the midst of hostilities?

(Signed) "JAMES BUCHANAN."

Great excitement prevailed and Field was the hero of the hour, but the cable worked with continually increasing difficulty, and at the end of 23 days after 732 dispatches had passed over the wire it became mute forever, and those who had so ardently praised Field but a few days before as hotly reviled him. Nevertheless, one of the last dispatches from the London War Office, countermanding the movements of the two regiments in Canada, had saved England an outlay of $250,000, and this fact was urged as showing the commercial value of a cable.

Like the Grecian giant who, thrown to earth, rose with strength redoubled, Field seemed to derive nothing but inspiration from failure and set about organizing another company, but the unrest in

financial circles that preceded the American Civil War and the struggle that ensued delayed the next trial until 1865. The war had shown that a cable would have prevented many misunderstandings between England and America, and the London *Times* afterward said, "We nearly went to war with America because we had no telegraph across the Atlantic."

The cable of 1865 was much larger and stronger than the other. The core of the 1858 cable weighed 107 pounds to the mile, that of the new one 300 pounds to the mile, and the insulation was calculated to be 100 times greater.

The "Great Eastern." The risk and inconvenience of dividing the cable between two great vessels had been shown, and Brunel's *Great Eastern* was chartered for the occasion, a work for which she showed herself particularly serviceable. On July 23, 1865, the shore end of the cable at Valentia was spliced to the cable coiled within the tanks of the *Great Eastern*, and the largest vessel afloat began her journey westward. Electrical instruments tested the cable from time to time as it was paid out. Three times faults were found, the cable brought in over the bows, repaired and lowered, but at the fourth attempt, when 1186 miles had been laid and the ship was only 606 miles from the end of its journey the cable broke. For nine days they grappled, and three times the cable was hooked and partially raised when the grappling ropes broke and away rushed the grappling irons, rope, and cable to the bottom of the ocean. It was only after there was not enough rope left to reach the bottom that a buoy was placed to mark the spot where the cable and their hopes lay buried, and Field steamed back to England to face the men whose capital lay at the bottom of the ocean.

With almost incredible courage, persistence, and persuasive power he explained, pleaded, argued, and so prevailed upon the capitalists that the Anglo-American Telegraph Company was organized Decem-

ber 24, 1865, and in fourteen days a capital of more than $3,000,000 had been pledged. A new cable was made and on July 13, 1866, the *Great Eastern* again connected a cable within her hold with the shore end at Valentia, steamed westward and after an uneventful voyage landed the cable end at Heart's Content, Newfoundland, July 27, 1866. The electrical connection was satisfactory and the cable at once went into operation. To make the triumph still greater the *Great Eastern* steamed back to where the cable had been lost in 1865, and after twenty days' fishing secured the end, made a splice, and on the 8th of September landed the second cable's end at Heart's Content, thus within 37 days completing two cables, both in working order, across the Atlantic.

Cyrus W. Field was born at Stockbridge, Massachusetts, November 30, 1819. When sixteen years of age, with $8 in his pocket he left home to make his fortune, and served as errand boy in A. T. Stewart's store in New York city, one year for $50. Eighteen years thereafter he was worth $250,000.

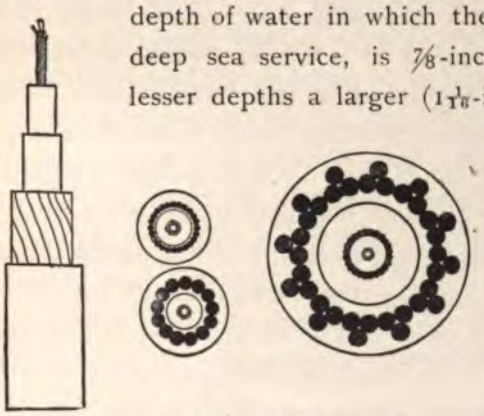
LAYING ATLANTIC CABLE.

Field died July 12, 1892, and during the closing months of his life was able to keep up the payments on his life insurance policies only through the kindly aid of a friend, J. Pierpont Morgan.

Later Efforts. Field's efforts smoothed the way for his successors, until now the laying of an Atlantic cable attracts no more attention than the building of a great bridge or the launching of a new battle ship, and competition has reduced cable tolls from one

pound ($4.86) to one shilling (25 cents) per word. The laying in 1894 of the third line of the Commercial Cable Company occupied but 20 days. This cable was laid by the especially equipped telegraph ship *Faraday*, on board of which 1700 miles of cable was coiled in three large tanks. At sea, the cable was run out over a large pulley at the stern of the ship. Between the tanks and the stern it passed over retarding mechanism which consisted of several wheels and a large brake wheel around which it passed several times. It then passed under the dynamometer, where the stress on the cable was accurately measured. During the whole time that the cable was being made and laid, electrical tests were made, so as to be sure that everything was in order, for a single fault would ruin the whole cable. When all conditions are favorable a cable can be laid at the rate of about seven nautical miles an hour.

Mechanism of Cables. Nearly all the great mileage of submarine cables has been manufactured in England on the banks of the Thames. Modern cables are made in four sizes according to the depth of water in which they are laid. The smallest, for deep sea service, is ⅞-inch in diameter; for somewhat lesser depths a larger (1 1/16-inch) size is used. The next size is 1¾ inches in diameter, and the land ends of all are about 2½ inches in diameter. The core in each is of the same size, the difference in diameter being due to extra thickness of the coverings. A submarine cable is made up of five layers. The inner one (core) is made up of a strand of twisted copper wires which constitutes the conductor of the electric force. For the purpose of



Sections of Submarine Cable.

insulation the core is covered with a layer of gutta percha. The third layer is a covering of tarred jute yarn wound in a spiral manner to protect the insulation from damage by the fourth layer, which is made of steel wires laid close together and slightly twisted, so that while they give the cable great tensile strength, they are also flexible and elastic. Around all this is pressed a layer of a bituminous compound to protect the whole structure from the action of the water.

A single machine performs all these operations, the core being fed to it in the form of copper wires, which the machine twists into the proper form and then presses the covering of gutta percha firmly around it. Next the jute yarn is fed in, and then the steel wires, each wire being pressed into its exact place and given the desired twist by the machine. The cable is then passed under a spout from which runs the melted bituminous compound, and is led into a circular press which sets it firmly to its proper shape and size, after which the cable is coiled in large iron tanks in which it is kept under water.

Gutta Percha is the hardened milky juice derived chiefly from a large tree which grows in Borneo and some other islands of the East Indies. It becomes soft and pasty at a temperature of about 115° Fahrenheit and can then be molded into any form desired. The cable running from Brest, France, to Cape Cod, Massachusetts, is 3250 miles in length, and yet the electric current finds it easier to traverse this immense distance through the copper wire of the cable's core than to pass through the quarter inch of gutta percha which covers it, for, compared with copper, gutta percha is about 1-60,000,000,000,000,000,000 as good a conductor of electricity. The supply of gutta percha is limited. It is reported that the gutta percha of Sumatra and Borneo is nearly exhausted owing to the reckless manner in which the trees have been cut, and German experts consider the Philippines the next field for the cheap and profitable production of gutta percha. The insulation required for the third

Commercial Cable raised the price of gutta percha 50 per cent. in the markets of the world. If to furnish insulation for a cable 2500 miles in length was difficult, what will be the cost of gutta percha for an All-British or American cable 7000 or 8000 miles in length to cross the Pacific ?

Breaks in cables are frequent, and deep sea cables are disabled so often in the East Indian Archipelago by earthquakes as to attract little attention. If a break or leak occurs the electrician calculates the distance to it by the *capacity* and *resistance* of the remaining portion of the wire. *Resistance* is the retardation that the wire causes in the passage of a current of standard intensity. *Capacity* is the amount of electricity a given amount of wire can hold and then give up at one discharge. When the cable is laid the resistance and capacity per mile, or even per foot, are determined. If the cable breaks in two, electricians measure the resistance of the remaining portion and by proportion calculate the distance to the break. A repair ship is then sent to the spot and the immense fishing job commences, for the ends of the cable may lie at a depth of a mile or two. A four-pronged grapnel is attached to a rope with a wire center making electrical connection with the grapnel. Where each prong joins the shank is a push-button that connects with the core of the rope. The grapnel is lowered and dragged across the bottom of the ocean. If it catches the cable the latter sinks into the hollow of the hook-shaped prong, presses the electric button, which signifies its capture to those on board by ringing a bell. An old and deteriorated cable must be handled with great care, and such jobs require patience and skill of a high order.

A Famed Point. On Cape Canso, the most eastern point of Canada, is situated the little village of Hazel Hill, which, though 50 miles by road and 30 miles by water from the nearest railroad station, is still the best informed point in America, for every item of impor-

tant news from abroad is known here before it reaches the sanctum of the most enterprising editor on the continent. Three cables of the Commercial Cable Company are landed here and, hardly a mile away, four cables of the American Cable Company. Fifteen thousand five hundred miles of ocean cables center here, and the news service of the whole world depends in a large measure on the delicate machinery at this point being kept in perfect working order by men who live and work in this isolated but far from lonely spot.

The McGill University at Montreal in 1891 set about determining the exact longitude of Montreal and other points on the Atlantic seaboard, reckoning from Greenwich, England. To work out the calculations it became necessary to know the exact time it took to send a telegraphic signal across the Atlantic, and for this purpose a circuit was established and the signal flashed from Montreal to Greenwich and return, 8000 miles, in one second. With the Pacific cable established, completing the electric chain, the highest flights of the imagination of the poet, "I'll put a girdle 'round the earth in forty minutes," will have been more than realized by the genius of the inventor. In practical operation, of course, more time is required. In 1884 a communication sent from New York to London and an answer returned in 45 seconds, held the record for some time, but in October, 1894, a message was sent by the third Commercial Cable from New York to London and an answer received in 5 seconds. September 21, 1894, a Manchester company sent a message to Victoria, British Columbia, over the lines of the Commercial Cable Company to the Canadian Pacific Telegraph Company and received a reply in 90 seconds. The total distance is 13,000 miles.

The deepest cable in the world is that laid in 1896 from New York to Cape Haytien with the Southern line connecting with South America and Santiago de Cuba. During the land battle of Santiago a message was sent from the White House to the battlefield and an answer returned in 12 minutes.

Uses of Cables. Cables play an important part in the strategy of war. The importance of the cable service while Cervera's squadron was playing "hide-and-seek" during the Spanish-American war has not yet been forgotten. For lack of a cable on January 8, 1815, thousands of brave men were killed and wounded at New Orleans because they did not know that a treaty of peace had been signed at Ghent fifteen days before.

Prior to the laying of the Atlantic cable, communication between New York and London might require anywhere from two weeks to a month, depending upon the weather. The New York *Herald*, under the management of the elder Bennett, fitted out swift dispatch boats to meet transatlantic ships some distance from New York harbor, catch the latest news from Europe, and hurry into the city with it for the exclusive benefit of that paper. To-day the Paris and New York editions of the same paper contain practically the same world news. The commercial world has become so accustomed to the cable that it would seem almost impossible to do without it. Transactions involving millions of dollars depend on each day's cable news.

An All-British Cable is now determined upon for the Pacific and when completed will give Britain the most extensive and perfect telegraphic system in existence, placing the nation in direct communication with all her colonies encircling the globe and with the fortified and garrisoned coaling stations of Hong Kong, Singapore, Trincomalee, Colombo, Aden, Cape Town, Simon's Bay, St. Helena, Ascension, St. Lucia, Jamaica, Bermuda, Halifax, Esquimalt, King George's Sound, and Thursday Island. It will also connect the following "defended ports," Durban, Karachi, Bombay, Madras, Calcutta, Rangoon, Adelaide, Melbourne, Hobart, Sidney, Newcastle, Brisbane, Townsville, Auckland, Wellington, Lyttleton, Dunedin. This Imperial Cable system means the laying of 25,000 miles of

cable at an expense of about $30,000,000. The British Pacific cable, the expense of which is to be borne by Canada, Australia, and the Home Government, will run from Vancouver on the Pacific coast of the Dominion of Canada, southwesterly about 3561 nautical miles, including slack, to Fanning Island, about 1000 statute miles south of Honolulu. The island is a coral reef only two or three feet above high water except in a few places, where it rises to about 10 feet. Picture the life of the operators in such a place, cut off from all society, but receiving each day the news from the capitals of the world. The cable will run from Fanning to Fiji Island, 2098 miles; Fiji Island to Norfolk, 961 miles; Norfolk to Queensland, Australia, 834 miles. Total, 7454 miles.

As a chain is no stronger than its weakest link, so a cable is no faster than its slowest section. The section from Vancouver to Fanning is 400 or 500 miles longer than any other cable in existence, and cable speed decreases as the square of the distance. Hence a cable twice as long as another will have but one fourth the speed.

For the control of the sea ships, naval bases and coaling stations are required, and that they may work together and with the greatest efficiency sure means of communication are necessary. A high British authority has said that the value of the English navy is increased more than one half by the system of submarine cables wholly under British control, connecting the colonies, coaling stations, and fortified ports.

An American Pacific cable affording communication with the Sandwich Islands and the Philippines is so necessary that it probably will soon be forthcoming. At present cables from Washington to Manila go: "To New York by land; to Valentia, Ireland, by cable; to Brighton, England, cable and land; to Havre, France, cable; to Marseilles, land; to Alexandria, Egypt, cable; to Suez, Egypt, land; to Aden, Arabia, cable; to Bombay, India, cable; to Madras, land;

to Singapore, Malayan Peninsula, cable; to Saigon, Cochin China, cable; to Hong-Kong, cable; to Manila, Philippine Islands, cable. Distance 14,000 miles. Number of transmissions fourteen."* The present cable rates to Manila from Washington are $2.38 per word, the government rate $2.255 per word, right of way messages three times the regular rate.

The War Department's messages to and from the Philippine Islands for five months averaged $27,114.12 monthly, 90 per cent. of which went to foreign corporations, or much more than enough to pay the interest on a Pacific cable. The following table shows two routes proposed, the distance direct plus 10 per cent. allowance for an extra length or slack that must be given to the cable.

	Miles		Miles
San Francisco to Honolulu	2286	San Francisco to Honolulu	2286
Honolulu to Midway Island	1254	Honolulu to Wake Island	2205
Midway Island to Guam	2523	Wake Island to Guam	1435
Guam to Dingala Bay, P. I.	1496	Guam to Dingala Bay, P. I.	1496
Total via Midway Islands	7559	Total via Wake Island	7422

The longest link of this cable would be less than the cable running from Brest, France, to Cape Cod, Massachusetts, and would give greater sending speed than the long link of the British cable running from Vancouver to Fanning Island. If both cables were completed, a cable 1000 miles in length connecting Fanning Island and Honolulu would be of great advantage to both countries as it would still allow communication in case a cable were broken by accident or cut in course of war.

Wake Island is situated in north latitude 19° 8′, east longitude 166° 31′. It is a low sandy island three miles wide and five miles long inclosing a lagoon. The island contains no fresh water, has but little

* Capt. G. O. Squire.

vegetation, is surrounded by reefs, and is swept over by spray and probably by breakers during heavy storms.

Guam is the largest and most southern of the Ladrone group of seventeen islands, and has a population of about 9000. The island has many low mountains ranging from 1000 to 1600 feet in height. The soil is fertile and the climate healthful.

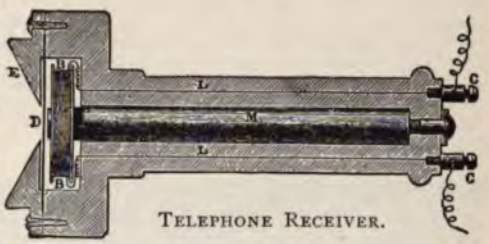
The receiving and sending apparatus of a submarine cable is most delicate. Although after Admiral Dewey cut the cable connecting Manila with Hong-Kong he buoyed both ends, he had no instruments nor was able to devise any by which he could establish cable communication. With the ordinary Morse instruments hardly a word a minute could be sent, and the use of strong currents is extremely objectionable.

The siphon recorder, invented by Lord Kelvin, consists of an ink siphon, one end dipping into the ink, the other suspended and touching a paper ribbon caused to move like the tape in a stockbroker's ticker. A powerful current of electricity sent through the ink causes it to flow very readily and the ink siphon forms part of a delicate piece of mechanism, which, like a magnetic needle, sways to right or left under the impulse of positive or negative electric currents and forms a zigzag line from which the message is read.

The mirror galvanometer is a minute mirror about 3/8 of an inch in diameter with a tiny magnet cemented to its back, the whole weighing not more than a grain, and suspended by a silk fiber. A lamp is placed so that its rays fall upon the mirror. The magnet on the suspended mirror yielding to the attraction of positive or negative currents rotates the mirror slightly and throws the rays of light upon a screen and their position to the right or left of a central point conveys intelligible signals to the operator who receives the message. The mirror galvanometer is also the invention of Lord Kelvin, who did more than any other man to render submarine cables efficient.

THE TELEPHONE.

Millions of dollars spent in litigation might have been saved had a clerk in the United States Patent Office Department been gifted with second sight and entered the *hour* of an application for a caveat "of a new art of transmitting vocal sounds telegraphically," filed by Professor Elisha Gray, and an application for a patent "for the electrical transmission of sounds or noises of any kind," filed by Alexander Graham Bell. Both applications were filed February 14, 1876, and the records do not show whether the caveat preceded the application or vice versa. The patent for a telephone was issued to Bell. Contests in the Patent Office and courts followed, not only with Gray, but with Edison, Berliner, Richmond, Holcombe, Dolbear, Volker, and others, and the decisions of the courts were always in Bell's favor.



TELEPHONE RECEIVER.

The telephone in its simplest form consists of a flat soft iron core having four permanent steel magnets arranged in pairs on opposite sides. One end of the core projects beyond the magnets and receives a wooden spool around which is wound numerous coils of silk-covered wire. A soft iron spacing-piece separates the opposite ends of the magnet, the ends of the wires from the coil are carried back to the other end, and the whole is inclosed within the familiar rubber handle with the two set screws at the end to which conductors are fastened. A round cap screws on to the handle and holds in position a thin plate of soft iron brought as closely as possible to the core of the magnet without touching it in any of its vibrations.

Bell's first telephone had a diaphragm made of gold beater's skin, to which was glued a circular piece of clock-spring. Words spoken before this drumhead set it in vibration as it approached and receded

from the core of the magnet and affected the magnetism and so set up slight variations in the strength of the electric current passing through the coil of the magnet. The wires from the coil were continued to another station and attached to an apparatus precisely similar and reproduced in the second instrument vibrations of the diaphragm that coincided exactly with the vibrations of the first, and so reproduced the like sounds that caused those of the first.

The apparatus first described will reproduce sounds and is commonly used as a receiver, but the transmitter is the work of Blake, Hughes, Gray, Edison, Berliner, and others, and is a more delicate instrument. When the transmitter was produced the telephone sprang into immediate use. The improvements consisted in the discovery that if a piece of carbon is rested lightly upon another and an electric current passed from one to the other in a circuit in which there is a Bell telephone receiver, the receiver will respond to the finest sounds in the vicinity of the carbon, because where two carbons touch, the contact is imperfect and the slightest disturbance of the current, of necessity, varies the resistance of the circuit, and this variation operates to produce sounds from the receiver. In the ordinary telephone that hangs on the wall, the transmitter is in the little box into which the talking is done.

UNDER SIDE OF A TELEPHONE SWITCHBOARD, SHOWING OVER 2,000 WIRES.

Unsolved Problems. As yet it has not been found practicable to send several telephonic messages simultaneously over the same wire and so long distance telephone wires cannot carry the amount of business of telegraph wires. The longest lines affording direct communications by telephone are: Boston to Omaha, 1556 miles; Boston to Kansas City, 1609 miles; Boston to Little Rock, 1793 miles. No really efficient instrument that will act for the telephone as the "relay" does for the telegraph has yet been invented, and the foregoing results have been achieved only by using large, pure, hard-drawn copper wires instead of iron. It is impossible with present instruments to communicate vocally through a submarine cable more than 27 miles in length.

Metallic Circuit. When the telephone first came into use much difficulty was experienced in using a single wire when laid near telegraph or electric wires because of the induced currents set up. The telephone is one of the most sensitive of electrical instruments and suffers from electrical disturbances too feeble to be felt by almost any other, hence is easily affected by any "induced currents" in its vicinity. To protect it from such influences it has been found desirable to employ, instead of a single wire running from station to station and connecting with the ground at the end, a metallic circuit. The circuit comprises two insulated wires of the same cross section laid together with a slight twist so as to average always the same distance from any disturbing wire.

The telephone has been a great boon to the Chinaman, who had no alphabet or written signs that could be reduced to a simple telegraphic code, and the sharp, high-pitched, jerky voice of the Chinaman seems particularly well fitted for long distance telephone business.

Arrangements are now made by which telegraphic and telephonic messages may be sent over the same line simultaneously. The tele-

phone does not interfere at all with the telegraph, but the latter produces a buzzing or knocking rather disagreeable to the hearer, but that feature is being overcome.

Although the telephone business dates only from 1877, one company alone, the Bell, had in 1900 1239 exchanges, 1187 branch offices, more than 1,000,000 miles of wire and more than 25,000 employees.

Wireless telephony is now an accomplished fact and employs simpler methods than the system of wireless telegraphy to which Marconi has given his name. In an address delivered in 1900 before the British Association, Sir William Henry Preece stated that his first experiments in wireless telephony were made in February, 1894, across Loch Ness. The trial showed that it was possible to exchange speech across the loch at an average distance of 1⅓ miles. "The sensation created in 1897 by Mr. Marconi's application of Hertzian waves distracted attention from the more practical, simpler, and older method. In 1899, I conducted some careful experiments on the Menai strait. No special apparatus seems necessary. The ordinary telephonic transmitters and receivers were used. It became desirable to establish communication between the islands or rocks known as 'the Skerries' and the mainland of Anglesey, and it was determined to do this by wireless telephony. The bottom of the channel is too rough and the currents too violent for a cable. A wire 750 yards in length was therefore erected along the Skerries and another on the mainland 3½ miles in length. Each line terminates by earth plates in the sea. The average distance between the parallel portions of the two wires is 2.8 miles. Telephonic communication is readily maintained and the service is a good one. Wireless telephony across the sea is now a practical and commercial system."

The Telautograph is an instrument invented by Prof. Elisha Gray by which a man's own handwriting can be reproduced in *facsimile* at

a distance, as though a man were writing with a pen having two points widely separated, both moving at the same time and making exactly the same motions. As the inventor says, "By this system a man may transact business with the same accuracy as by mail and with the same celerity as by the electric telegraph. A broker may buy or sell with his own signature attached to the order and do it as quickly as he could by any other method of telegraphing and with absolute accuracy, secrecy, and perfect identification." It was the inventor's idea that the telautograph should be used in connection with the telephone, an ordinary switch being sufficient to connect the two systems and permitting them to be used interchangeably.

Signaling through Water. The closing day of the nineteenth century witnessed a successful experiment conducted by Prof. Elisha Gray and Arthur J. Mundy of Boston before scientists from Harvard and officers of the United States navy. A boat equipped with an 800-pound fog bell was able to transmit sounds under water at distances of 1½, 4, 8, and 12 miles in the open sea. The electric current was supplied by a small dynamo driven by a gasoline engine. The bell was lowered through a well-hole in the center of the boat until 20 feet below the surface of the water and made to ring continuously or any desired number of strokes at the will of the operator.

If dangerous rocks were indicated by such a bell, a vessel might be fitted with an electrical receiver which would ring a gong on board the ship when approaching within range of the signal sent from the bell and thus receive warning of "the perilous rock."

It is of course obvious that by equipping ships with these sound producers and sound receivers, intelligible messages may be sent back and forth, either between ships or between ships and the shore. Again, vessels thus equipped may avoid collision by notifying each other of their approach and the direction of their course. Again,

light-ships can be put into communication with the shore by merely anchoring a submerged receiver within a short distance of the light-ship, which, being equipped with a submerged bell, can announce the arrival of incoming vessels. This is a problem which has bothered the government, owing to the difficulty of attaching a telegraph cable to a ship which is swinging around a mooring.

The electrical receiver can be used for detecting the approach of a submarine torpedo boat, the noise of which can be plainly heard at a distance of several miles, the sound being intensified by the fact that the submerged boat must transmit all its vibrations to the water, which incloses it on all sides. Even small steam tugs on the surface of the water can be heard at a distance of two miles, the click of their machinery being distinctly audible. In the latter case only a fraction of the sound produced by the tug enters the water, most of it being transmitted through the air; but a submarine boat must give all her vibratory noises to the water. As the receiver will tell the direction whence the sounds proceed, the war ship thus attacked may choose between running away or waiting till the torpedo boat comes within range and then fighting her with her own weapons under water.

Professor Gray died suddenly with neuralgia of the heart January 20, 1901. He was eminent for his discoveries in electrical science and a party to the famous 25 years of litigation with Professor Alexander Graham Bell concerning the priority of invention of the telephone. Professor Gray believed that his caveat was disclosed to Professor Bell after it was filed, and this and the long litigation embittered his late years. He died poor, although he received comparatively large sums from time to time for his inventions, but invariably used the money in expensive experiments. At one time his home was filled with beautiful pictures and statuary, which financial reverses compelled him to sell.

THE PHONOGRAPH.

The phonograph, invented almost a quarter of a century ago, has become so familiar that some have lost a proper appreciation of its worth. It is another one of those "accidental discoveries," but like most accidental discoveries required the presence of an alert educated mind, quick to see and appreciate phenomena that would have escaped the attention of a duller person. Mr. Edison says of the phonograph: "My discovery came to me almost accidentally, while I was busy with experiments having a different object in view. I was engaged upon a machine intended to repeat Morse characters, which were recorded on paper, by indentations that transferred their message to another circuit automatically when passed under a tracing point connected with a circuit-closing apparatus. I found that when the cylinder carrying the indented paper was turned with great swiftness it gave off a humming noise, a musical rhythmic sound resembling that of human talk, heard indistinctly. This led me to try fitting a diaphragm to the machine, which would receive the vibrations or sound waves made by my voice when I talked to it and register these vibrations upon an impressible material placed on the cylinder. The material selected for immediate use was paraffined paper and the results obtained were excellent. The indentations on the cylinder when rapidly revolved caused a repetition of the original vibrations to reach the ear through a recorder, just as if the machine itself were speaking. I saw at once that the problem of registering human speech so that it could be repeated by mechanical means as often as might be desired was solved." Such was the germ of the invention, and the rest of the problem was the perfection of the mechanical means of carrying out the idea, but it was ten years before Edison produced a machine that he was satisfied to put upon the market.

The Phonograph in its early form consisted of a cylinder with

spiral grooves on the surface covered with a layer of tin foil. Through the center of the cylinder passed a rod on which it revolved. The inside of the cylinder and the outside of the rod were fitted with threads so that as the cylinder was turned it gradually moved toward one end of the rod and brought the whole length of the cylinder opposite the mouthpiece. The mouthpiece contained a diaphragm something like that in the telephone but had attached a fine metal point. When the mouthpiece was spoken into, the tones of the voice caused vibrations in the diaphragm and the point attached made minute indentations on the tin foil surface of the cylinder revolving underneath it. To reproduce the speech the process was reversed, the cylinder returned to its original position and again revolved. As the indentations passed rapidly underneath the metal point the diaphragm was made to vibrate as before and tones similar to those that had caused the indentations in the first place were reproduced. The tones of the first phonograph were harsh and metallic in the extreme but the most objectionable features are being gradually removed or reduced.

The Graphophone, the invention of Bell and Tainter, first patented in 1886, covered a great improvement in the phonograph record. In this a cylinder covered with wax was substituted for the tin foil. The point of the diaphragm cut a distinct groove .0006 of an inch deep instead of tracing a dotted spiral line. Such a cylinder was more positive in its action and more easily handled. A wax cylinder once used can be put in something resembling a lathe and a tiny shaving just deep enough to remove the groove of the first record turned off and the cylinder used again.

The Gramophone, another talking machine, is the invention of Emile Berliner, patented in 1887. Instead of a wax cylinder this uses a flat disc on which is a sheet of zinc covered by a layer of wax on which a needle attached to a diaphragm traces a record in a spiral

gradually approaching the center of the plate. When the record is complete, the zinc plate with its wax covering is removed and the surface etched with acid, when an electrotype may be made from it. From the electrotype hard rubber records can be made capable of giving 1000 reproductions.

About 300 patents have been issued for talking machines, and making records is a well recognized business of considerable importance. The recorders and reproducers are instruments of great nicety, using diaphragms of French glass as thin as the leaves of this book, and sapphire points of extreme hardness for the stylus and the turning tool that smooths the surface of the record for a new speech.

Speaking machines range in price from $5 to $200, and wax cylinders holding from 200 to 1200 words cost from 25 cents to $3. One of the most important parts of a talking machine is the motor, which must give a uniform rate of speed, and a good deal of ingenuity has been lavished on this part of the machine. The speaking machine has found a place among home amusements but has not come into general business use, probably because records are not made that will suffice for more than five or ten minutes' dictation, hence requiring frequent changing and interruption that the business man does not welcome.

Posterity is likely to set a high value upon the phonograph if it can be perfected until it will preserve a true record of the natural tones of the human voice. What would not the Present give for true records of the Past that would reproduce for them the eloquence of Pitt, Burke, Fox, Bossuet, Cæsar, Cicero, or Demosthenes, the farewell address of Washington, the Gettysburg speech of Lincoln, the stirring scenes of the French Revolution, or, more impressive than all, that famous scene before Pilate?

MOVING PICTURE MACHINES.

Moving picture machines, by whatever name known, are all based upon the principle of the duration of visual impressions. Leonardo da Vinci in the fifteenth century interested himself in the theory of visual impressions, and the theory at one time or another has engaged the attention of numerous scientists no less eminent than Herschel and Faraday.

The duration of an impression of light on the retina of the eye varies from 1-10 to 1-50 of a second, being longest after a short exposure to violet light and shortest after exposure to intense yellow light. Hence if a series of pictures of an object in different positions are passed before the eye with an interval not greater than 1-50 of a second, the impression of continuous motion is produced.

The Zoetrope, a toy invented in 1832 by Plateau, a Belgian physicist, was one of the earliest of the family of moving picture machines. Plateau's studies of vision cost him his eyesight about the middle of his life, yet in spite of this, through the aid of members of his family, he was able to conduct many experiments and contribute much to our knowledge of how we see.

The zoetrope is a cylinder from 8 to 12 inches wide and a few inches high with slits in the upper half. Around the lower half are a series of pictures showing men or animals in various moving attitudes. The cylinder rests on a base, upon which it revolves. Each picture, viewed through the narrow slits in the top of the cylinder as it rapidly revolves, creates a visual impression, which, before it has time to fade away, is succeeded by another until the impression of continuity is produced and the eye seems to behold the animals executing various motions. Such toys had poorly executed pictures made by hand, and it was not until the camera was pressed into service that lifelike effects were produced.

Edward Muybridge. Horses in motion were first successfully

photographed in 1872 by Edward Muybridge, who was the first to utilize sensitized films of gelatin bromide of silver emulsion for the purpose of taking pictures of animals in motion. He arranged a series of cameras beside a race track and connected the shutter of each with a frail thread which broke when the horse struck it, and operated the shutter, thus furnishing a series of pictures in close succession within a second or two of time. To better exhibit his pictures he devised an instrument he called the zoöpraxiscope, in which a glass disc about 10 inches in diameter was employed, the small pictures being mounted near its circumference. The disc was made to revolve and each picture in turn thrown on the screen by the aid of a projecting lantern, where they were reproduced with striking effect. But there was so much expense and so many difficulties connected with the work that it could never become widely used, although it produced a profound sensation and was plainly the forerunner of the kinetoscope, vitascope, and cinematograph. Among artists Meissonier of France and Remington of America were quick to catch the hint from the camera and reproduce it with their pencils. Although their first productions excited a great deal of criticism, closer observation proved them to be correct.

Kinetoscope. In 1887 while Edison was working on the phonograph the idea occurred to him of producing a machine that would present a moving picture of the speaker, and in 1897 he successfully realized this idea in the kinetoscope. He employed instead of Muybridge's series of cameras a special camera (kinetograph) to take the pictures. He used as a carrier for the sensitive film a long transparent strip of celluloid 1½ inches wide. The pictures are an inch wide, a row of perforations along each edge of the strip taking up the rest of the space. "These perforations occur at close and regular intervals, in order to enable the teeth of a locking device to hold the film steady for 9-10 of the 1-46 part of a second, when a shutter

opens rapidly and admits a beam of light, causing an image or phase in the movement of the subject. The film is then jerked forward in the remaining 1-10 of the 1-46 part of a second, and held at rest while the shutter has again made its round, admitting another circle of light, and so on until 46 impressions are taken a second, or 2760 a minute. This speed yields 165,600 pictures in an hour, an amount amply sufficient for an evening's entertainment, when unrolled before the eye. . . . . In this connection it is interesting to note that were the spasmodic motions added up by themselves, exclusive of arrests, on the same principle that a train record is computed independent of stoppages, the incredible speed of 26 miles an hour would be shown."

After the film has been exposed it is developed and produces a negative from which a positive is made by printing and developing in the usual manner. To use the positive it is passed through the slide aperture of a stereopticon fitted with a starting and stopping device corresponding exactly in time with the mechanism which made the exposures. The pictures can be viewed through a stereoscopic glass, a magnifying glass, or the image can be projected life-size on the screen in view of an audience.

The Kineto-Phonograph is simply a kinetoscope accompanied by the usual phonograph machine adapted so as to work harmoniously with it. The records for the two are taken simultaneously and are reproduced in such a way that the corresponding scenes and sounds are given out at exactly the same time.

POSTAL SERVICE.

The origin of the postal service dates back to the lines of couriers established by rulers before the dawn of history, and records are being continually brought to light to show that those were no mean organizations and that a pretty fair system of communication was

maintained at a very early age between Assyria and Egypt. Marco Polo tells us that the "Great Khan" maintained 10,000 post stations and more than 300,000 horses for the use of his messengers.

The first letter post for commercial purposes seems to have been established by the Hanse towns, the "free cities" of northern Europe, early in the twelfth century, and a century later France had a fairly efficient postal system established by the University of Paris and one which lasted until the beginning of the eighteenth century. England as early as 1252 had royal messengers, but it was not until the time of Henry VIII. that the regular system of posts was established in that country. James I. in 1609 forbade all persons not duly authorized from carrying and delivering letters, and this was the beginning of the government monopoly of letter-carrying in England, but it was not until 1680 that a person in London could communicate by letter with another residing in a different part of the same city. In 1754 a monthly mail went from Edinburgh to London occupying from twelve to sixteen days, and the journey was both trying and perilous. Until Sir Rowland Hill began in 1837 his agitation for cheap postage, it cost in England 8 cents to send a letter any distance less than 15 miles; 10 cents for distances over 15 and under 20 miles; 12 cents, over 20 and under 30 miles; 14 cents over 30 and under 50 miles; 16 cents, over 50 and under 80 miles; the rates increasing with a rapidity that was prohibitive. In 1840 the average number of letters per person in England was a little more than two per year. In 1893 there were delivered an average of 46.6 to each person.

Canadian System. In Canada until the time of the Confederation in 1868 each province controlled its own postal system and the rates were curious, perplexing, and not well calculated to foster the development of the system, but after the Confederation the rate was reduced to three cents per ounce and recently to two cents. For the

year ending June 30, 1893, there were reported 8475 offices, handling 222,419,000 pieces of mail matter, a high average per capita. Canada joined the postal union in 1879 and has an excellent postal service.

In the United States only the most primitive methods at first existed, but gradually a postal service grew up and was established between the several colonies along the coast, and in 1672 there was "a post to goe monthly from New York to Boston." A Post Office Department was organized soon after Washington's inauguration in 1789, and Samuel Osgood of Massachusetts appointed Postmaster General. To assist him in the arduous performance of his duties he was allowed one clerk and found this more than sufficient, for there were only 75 post offices and 1875 miles of postal roads in the whole United States. Such was the humble beginning of a postal establishment that has grown to be the greatest business concern in the world, for according to the official report for the year ending June 30, 1899, there were 496,248 miles of postal routes and the mileage traveled in the course of the year was sufficient to make two round trips to the sun. The total number of pieces mailed during the year was 6,576,310,000, weighing 664,286,868 pounds, to carry which would require 33,214 freight cars forming a train 300 miles long and hauled by 500 locomotives. For the year ending June 30, 1900, there was collected at the New York post office $10,905,087. As an illustration of the growth of the system and of the country, the receipts for the same year at Minneapolis were $663,206, and the town was first settled in 1849.

Postal Union. In October, 1874, representatives from all the states of Europe, the United States, and Egypt met at Berne, Switzerland, in response to the invitation of Germany, for the purpose of devising a system that would give greater uniformity and better service to the postal organizations of the different countries.

A system was agreed upon, a union was organized, and a central post office established at Berne, under the supervision of the Post Office Department of Switzerland, for the purpose of taking notice of and working out all the problems of interest to the organization. Such conventions are now held every three years and nearly all the countries of the world have joined the union, which has brought about many desirable changes, greatly increased postal facilities, tended to make the countries better acquainted, and to knit the ties of good feeling among nations.

Free Delivery. England, France, and Germany have "rural free delivery." Such a system is possible in countries thickly populated, for England contains 50,867 square miles, France 204,092 square miles, and Germany 208,830 square miles. Experiments have been made in the United States, and November 15, 1900, 2614 rural free delivery routes had been located, covering 66,842 square miles, divided among 44 states and territories, and serving a population of 1,801,524. The service has proved satisfactory and the advantages are so marked that opposition is fast subsiding and the movement is meeting with cordial approval and support. A farmer brought into daily contact with the business world has a more accurate knowledge of ruling markets and varying prices, and the values of such farms are in many cases considerably enhanced. Good roads follow as a natural sequence, adding still further to their value, and the material and measurable benefits are signal and unmistakable.

Pneumatic tube postal service was first tried by Denis Papin in London in 1667, but his experiment was so much in advance of the requirements of the service that his scheme was not considered a success. In 1853 a practical system was installed in London reaching from the Founders' Court to the Stock Exchange, a distance of 220 yards. The first extensive system appeared in Berlin and was put in operation by Siemens and Halske in 1865. It was 5760 feet

long and composed of a double tube, one for sending, the other for receiving, messages, and here the plan was first adopted that makes the system really practicable, for one end of the line was connected by a loop and the other contained an air pump which drew its supply of air from the receiving tube and pumped it into the sending tube, producing a partial vacuum in one tube and compressing the air in the other, thus performing a double duty.

Berlin has at present 28 miles of double pneumatic tube, 2.55 inches in diameter. Paris has about 25 miles of tube, with carriers moving at the rate of 23 miles an hour. London has 34 miles of such system with tubes 3 inches in diameter, and Manchester, Birmingham, Glasgow, Liverpool, Dublin, and Newcastle all employ this system for rapid distribution of the mails.

America has only about 8 miles of pneumatic postal tubes. In 1893 the main post office of Philadelphia was connected by 6-inch tubes with a sub-station on Chestnut street. The increase in size, speed, and carrying capacity made this line several times more efficient than any previous system.

New York post office was fitted in 1897 with a system having 8-inch tubes and carriers with a speed of 30 miles an hour. This system in one year saved 76,312 miles of wagon service and reduced the Brooklyn delivery to three minutes where the wagons had consumed twenty-five minutes.

Description of Pneumatic Carriers. The carriers are hollow cylinders of metal with a packing ring at each end which prevents the air passing around them. The air pressure is continuous and by means of clever devices the carriers are put into and taken out of the tubes without interrupting it. The transmitter can best be described as a section sawed out of the tube and hinged so that its rear end can be swung out and at the same time a plate swung in to close the tube, and prevent the escape of air, the current going through a

switch (by-pass) which opens when the transmitter swings out. The loaded carrier is pushed into the free end, the section is swung back into place, the by-pass closing at the same time, and the carrier starts on its journey. All the sender has to do is to manipulate a lever which controls the swinging apparatus, and compressed air does the rest. A loaded carrier traveling at a speed of 30 miles an hour has a momentum not to be lightly trifled with, so a stopping device is necessary. At the receiving station a long section of the pipe is hung on trunnions. The end of this tube has a valve set to allow the escape of air when the pressure exceeds that of the regular tube pressure, and a "by-pass" allows the current of air to pass from the receiving tube to the sending tube. When a carrier arrives at the station it plunges into the blind tube and its momentum compresses the air and sets in motion a mechanism which swings the tube on its trunnions and closes the end of the line. The carrier is stopped by the cushion of air in the end of the tube, and the valve leaves just enough pressure to force the carrier to the open end of the tube and throw it out upon a table. As soon as the tube is delivered of the carrier, a counterweight swings it back into line and it is ready for another carrier.

The New and the Old. A two-cent stamp will carry a letter from Maine to the Philippines, a journey that would cost $300 for the fare of a messenger, and a part of the way would be traveled at a speed that would have no charm for a timid person.

In 1889, the time of the transcontinental mail from New York to San Francisco was 5 days, 8¼ hours. This was gradually reduced until January 1, 1899, a new system was inaugurated which regularly covers the 3408 miles in 98½ hours or an average of 34½ miles an hour for the whole distance, including all stops and transfers of mail bags, the latter consuming considerable time, for in Chicago they are carried across the city in a wagon. The engines are changed

eighteen times, the postal crews seven times, and the actual running time of the train frequently exceeds 75 miles an hour for long stretches. Yet all this is the work of a single generation and there are men now living, notably "Buffalo Bill," who have helped carry the mail on horseback from the Mississippi to the Coast before the advent of the railroads.

St. Joseph *News* (Missouri) says: "In 1859 St. Joseph was the terminus of railroad communication. Beyond, the stagecoach, the saddle horse, and the ox trains were the only means of commerce and communication with the Rocky Mountains and the Pacific Slope.

"The discovery of the gold fields had brought sudden importance to California and the demand for speedy communication was emphatic and insistent. A lobbyist tried to secure a contract for carrying mails overland one year for $5,000,000. William H. Russell, backed by Secretary of War Floyd, resolved to give the lobby a cold shower bath. He offered to bet $200,000 that he could establish a line from Sacramento to St. Joseph, 1950 miles, that would cover the distance in 10 days. The bet was taken and the 8th of April fixed as the day of starting. Mr. A. B. Miller, Mr. Russell's general manager, purchased 300 of the fleetest horses he could find in the West and employed 125 men, 80 of them for post riders. These he selected with reference to their light weight and their known daring courage. It was essential the load should be as light as possible; the lighter the man the better. The horses were stationed from 10 to 20 miles apart and each rider covered 60 miles, it being necessary to make a portion of the route at the rate of 20 miles an hour. Two minutes was the schedule time for changing animals and shifting the mails. Where there were no dwellings at a proper distance, tents large enough to hold one man and two horses were provided.

"Indians sometimes gave chase but their cayuse ponies made

but a poor showing in pursuit of Miller's thoroughbreds, some of which could make a single mile in a minute and 50 seconds.

"Arrangements being completed, a signal gun on the steamer at Sacramento proclaimed the meridian of April 8, 1860 — the hour for starting — when *Border Ruffian*, Mr. Miller's private saddle horse, with Billy Baker in the saddle, bounded away toward the foot-hills of the Sierra Nevadas and made his ride of 20 miles in 49 minutes.

"The snows were deep in the mountains. One rider was lost for several hours in a snowstorm, and after the Salt Lake valley was reached additional speed became necessary to reach St. Joseph on time. When the rider struck the Platte at Julesburg the river was up and running rapidly but he plunged his horse into the flood, only to see him mire in the quicksand and drown. The courier swam to the opposite shore with mail bag in hand and traveled 10 miles on foot to the next relay.

"Johnny Fry, a popular rider of his day, was to make the finish. He had 60 miles to ride with 6 horses to do it. When the mail was turned over to Fry it was one hour behind time. A heavy rain had set in and Fry had only 3 hours and 30 minutes to cover the course, and $200,000 might turn on a single minute. This was the finish of the longest race for the largest stakes ever run in America. At least 5000 people gathered at the finish and turned anxious eyes toward the woods from which the horse and its rider should emerge into the open country, one mile from the finish. Tick, tick, went the thousands of watches. The time was nearly up! But nearly seven minutes remained. Hark! A shout goes up from the assembled multitude. 'He comes! he comes!' The noble little mare, *Sylph*, the daughter of *Little Arthur*, darts like an arrow from the bow and makes the run of the last mile in one minute and fifty seconds, landing upon the ferry boat with five minutes and a fraction to spare."

PHOTOGRAPHY AND PRINTING.

Early History of Photography — The Energy of the Sun's Rays — The Chemistry of Photography — Photography of the Heavens — Photo-Engraving — Half-Tone Engraving — Roentgen Rays — Crookes Tubes — Homemade Apparatus for X-ray Experimentation — Paper and its Early Substitutes — Papyrus — Parchment — Paper Making — Transition from Forest Tree to Newspaper — The Art of Printing — Its Early History — The Evolution of the Printing Press — Capacity of the Latest Press — Type-setting Machines — Color Printing — Linotype — Empire Type-setting Machine — Stereotyping — Evolution of the Modern Typewriter.

EARLY History of Photography. The photograph is the product of the last hundred years, and the gap which separates the first rude scrawls of the primitive artist on the reindeer's bone from the productions of the pencil of a Michael Angelo, is narrower and represents fewer difficulties overcome and problems solved than that which intervenes between that pencil and the half-tone and photograph of to-day. The difference between the work of the savage with his flint tool and the artist with his pencil is only in degree and not in kind, while the camera stands for mysteries solved and additions to the sum of human knowledge so far-reaching in their effects that no man can fix their boundaries. The camera has revolutionized art and made the eye familiar with things that were before invisible. It preserves for man the features of his friends, and the scenes of his greatest happiness. It furnishes the physician with permanent pictures of the bacteria revealed by his microscope, and with it the astronomer photographs stars so faint as to be invisible to the eye, though aided by the most powerful telescope.

It is now known that the sun's rays have three forms of energy, or produce three effects: optical, thermal, and chemical. A ray of sunshine passed through a prism resolves itself into the well known prismatic colors: red, orange, yellow, green, blue, indigo, violet. The heat rays are most powerful at the red end of the spectrum and extend into the darkness beyond the range of the eye. On the other hand, red rays affect salts of silver hardly at all, but the violet end of the spectrum acts upon them vigorously, the most energetic rays being in the darkness outside of the violet. The light waves then appear to occupy the middle of the spectrum, for at each end, as we have seen, are powerful rays invisible to the eye.

Photography is based primarily upon the power of the sunlight to blacken the salts of silver. The camera of to-day does not differ greatly in essentials from the camera obscura, which has been credited to numerous persons, from Roger Bacon (1214–1294) to Leonardo da Vinci (1452–1519) and Baptista Porta (1538–1615). The camera obscura was often used by landscape painters to throw a real image of a distant scene upon a drawing board within a dark room. The pencil of the artist then reproduced the scene. The camera of to-day substitutes for the drawing board a sensitized film or plate, in place of the pencil employs the rays of the sun, and thus equipped, the veriest amateur obtains results that the greatest artist could not have equaled. In 1566 the alchemist Fabricus discovered that horn silver blackened on exposure to light, and yet hundreds of years passed before the relation between the silver and the camera was perceived and the pocket "kodak" made possible.

Eighteenth Century Experiments. Johann Schults of Halle in 1727 tried to make copies of written characters by treating paper with silver nitrate and exposing it to light, but his apparatus was crude and his method not successful, although his idea was clear and the light of photography was apparently dawning.

Carl Scheele in 1777 continued experiments with silver chloride and proved that the blue and violet end of the solar spectrum was the most potent on the salts of silver. Jeremiah Ritter of Silesia demonstrated in 1801 the existence of powerful though invisible rays beyond the violet end of the spectrum.

Sir Humphry Davy in 1802 published a brief paper on the "Method of copying paintings upon glass and of making profiles by the agency of light upon nitrate of silver." The merit of the invention, as the paper showed, belonged exclusively to Thomas Wedgewood, brother of Josiah Wedgewood, the famous potter, Davy simply explaining the nature of the discovery. Davy concluded by saying, "Nothing but a method preventing the unshaded parts of the delineation from being colored by exposure to the day is wanting to render this process as useful as it is elegant."

Many investigators caught fleeting pictures on prepared paper, but when exposed to the sun's rays they vanished, for the light that produced also destroyed. We find the very remarkable statement on doubtful authority that one Francis Eginton, in the employ of Boulton and Watt, was able to give permanency not only to the image of the camera obscura but also to its colors. Eginton was progressing well with the work when the government ordered it stopped and gave him a pension of £20 a year on condition that he never reveal the secret, because if such a process were known the painters of the country would be deprived of their means of livelihood. The matter is said to have been kept secret until accidentally discovered in 1863, but all records of the methods had been destroyed by the government in 1790, though it is claimed that a record of the achievement and the picture still exist.*

The light of photography is next found shining upon Joseph Nicéphore Niépce about 1814. Becoming interested in the study of

* *Fortnightly Review.* Volumes 20-64.

lithography, then newly discovered, he finally gave a metal plate a thin coat of a solution of asphalt and exposed the plate to the action of light in a camera, when he found those parts of the plate acted upon by the light had become insoluble while the parts that had been in the shadow could be washed away with oil of lavender and petroleum. He next poured over the plate a corrosive acid which attacked the exposed portion while the asphalt protected the other parts from its action. The plate was then washed with water, the rest of the film carefully removed, and when ink was pressed into the lines made by the acid, photographic etching was discovered. By 1826 he was able to copy engravings, but his plate required a long exposure which unfitted it for ordinary photography.

The Daguerreotype. Louis Jacques Mandé Daguerre, a scene painter, was working on the same problem and in 1829 formed a co-partnership with Niépce, but unfortunately the latter died in 1833, before any complete success was attained. Daguerre used a copper plate coated with silver and carefully polished. This he held in fumes of the vapor of iodine and produced silver iodide. Exposed in the camera, a fine image was taken that defied all his efforts to fix. About this time his wife became alarmed and consulted her family physician concerning her husband's sanity. The incident reminds one of the papers said to be on file in a Baltimore court setting forth that the relatives of Morse desired his incarceration on the ground that he had asserted that it was possible to communicate a long message from Baltimore to Washington within one minute. Almost discouraged, Daguerre was persuaded to cease his efforts and

DAGUERRE.

he locked up a number of unsuccessful plates in a closet and rested. But the subject was so fascinating that he could not resist it. To his surprise, when he opened his closet door each of his defective plates had a permanent picture, not visible when he set them away. A number of chemicals were present with the plates and he suspected them of this occult influence. After a long process of elimination a cup of mercury was forced to plead guilty. The vapors of the mercury, for mercury vaporizes at ordinary temperature, had been deposited on the plates and in some mysterious way the part of the silver iodide that had been struck by the light had the power of holding mercury while it was rejected by the other parts, which could be washed away with a solution of common salt without affecting the mercury tracings. The daguerreotype had rewarded his efforts. The French government bestowed on him a pension of 6000 francs, and a pension of 4000 francs on the son of Niépce, who had assisted Daguerre in his work.

THE FIRST SUN PICTURE OF THE HUMAN FACE. DOROTHY DRAPER.

So many improvements have been made in photography that only the tintype bears any close resemblance to the daguerreotype. The former is made on a thin iron plate covered with black enamel, to protect the iron from the corrosive action of the chemicals and to furnish a black background. The picture is really a negative but so

thin that the black background of the plate shows through the light portions of it and in reflected light causes it to look like a positive.

Efforts of Morse and Draper. Samuel F. B. Morse had been a portrait painter and had tried unsuccessfully to take captive the fleeting image of the camera obscura. Visiting Paris and hearing of Daguerre, he called on him and invited him to inspect the telegraph. In return Daguerre showed him the new process for making pictures and Morse took back to America some of Daguerre's materials. When the pension was granted, Daguerre sent Morse all the details of the process, and in September, 1839, the first daguerreotype in America, that of the Unitarian Church in New York city, was taken. Amateur photographers may be interested to know that an exposure of 15 minutes was required. Morse tried repeatedly without success to take portraits. He called to his aid Prof. John W. Draper of New York University, at that time the most eminent scientist in New York, and Draper succeeded, as shown by the copy of the first sun picture of the human face on preceding page. In the first portraits the sitter must have the face dusted with white powder and sit in a strong sunlight for half an hour with eyes closed without moving a muscle. Draper did away with the necessity of whitening the face and reduced the time of exposure to a few minutes. Daguerreotypes were expensive and in 1851 cost from $1.50 to $15 according to size and could not be copied except by electro-chemical methods.

The present system of photography more nearly resembles the process made public January 31, 1839, by Fox-Talbot, who discovered a process by which any number of positives or proofs could be

made from one negative. He washed a sheet of fine paper with potassium iodide, dried it, washed it with silver nitrate solution and a little acetic acid, and thus secured a paper charged with silver iodide. Just before using, to increase its sensitiveness, he dipped it in a mixture of silver nitrate and gallic acid. He exposed the paper in the usual manner in the camera, "developed" it in gallo-nitrate bath, and immediately upon the appearance of the picture plunged it into pure water and stopped the action of the bath. He "fixed" it in a bath of salt and water. The negative was next waxed to render it more transparent and any number of positive prints on sensitized paper could be taken from it. The glass plate was the invention of Sir John Herschel in his efforts to find something more transparent than the wax paper. To Herschel is also due the "hypo" fixing bath.

The albumen process was the next marked improvement. It was invented by Niépce St. Victor, a nephew of the "Columbus of Photography." He mixed the whites of eggs (albumen) with an equal quantity of water, added a little potassium iodide and allowed it to settle. On flowing the mixture over a sheet of glass it gave a thin sensitized film. The plate was then heated almost to the boiling point of water, which rendered the albumen insoluble, then dipped in a solution of silver nitrate and kept from the light. This gave finer results than the Fox-Talbot process.

Dry plates were brought about by the efforts of numerous investigators to overcome the inconvenience of wet plates. The result was reached by washing off the excess of silver nitrate after the bath in that solution and brushing the surface of the plate with some preservative and drying.

The collodion process was invented in 1851 by Scott Archer, who acted upon the suggestion of Le Gray of Paris and substituted a solution closely allied to gun cotton for the albumen of St. Victor.

The plates were used while wet. The process was more certain in its results than any previous one and for 25 years was the one chiefly employed. Dry plates were an improvement in some ways over the wet process for it made possible much out-of-door work, but required a longer exposure.

The emulsion processes employ a viscous liquid, usually gelatin, with which the necessary chemicals are actually mixed instead of being deposited on the surface as in the old dry collodion plate. These do not deteriorate so quickly, can be made very sensitive, and are a great improvement over the wet process with all its paraphernalia of trays, baths, and bottles. It greatly increased the efficiency of the camera and widened its sphere, made it applicable for use in connection with the telescope and the microscope, and rapid enough in its working to photograph a horse in motion, a cannon ball in its flight, or a flash of lightning. Emulsion films have been produced so sensitive that they are said to work with an exposure equivalent to 1-5000 of a second.

The roll film carried on paper was patented in England by A. J. Melhuish in 1854. In 1856 films appeared in which collodion or gelatin were substituted for paper, and such films have now been brought to a high state of perfection by Eastman, Walker & Co. of Rochester, N. Y. The film has been a boon to travelers, enabling them to "load" the camera in daylight and reduce the bulky, heavy, plate holding camera to the folding pocket kodak.

We may believe that Roger Bacon was the first to describe the camera about 600 years ago. Fabricus added his observations on discovery of horn silver 300 years after, but it required 300 years more to put the two together and form them into the pocket kodak where, according to the advertisement of the manufacturers, "You press the button and we do the rest."

How the Picture is Made. The rays of light from the object to

be photographed pass through a lens in the front of the camera which throws them upon a sensitized plate or film in the back of the box. Those rays coming from the lightest color of the object to be photographed have the greatest actinic power and produce a corresponding effect upon the plate. The rays of light from the object falling upon the plate have a "reducing" effect upon the salts of silver.

After the exposure the plate is carefully protected from the light, carried into a dark room, and "developed." The development of a latent image on a photographic plate traces back to the mercury bath of Daguerre. Developers continue the process of reduction set up by the sunlight. In a pyrogallic bath the developer reduces the silver nitrate in the film to finely divided metallic silver and deposits it on those parts of the plate upon which light has acted the more forcibly and in proportion to that action. The developer does not affect the iodide, bromide, and chloride (haloids) of silver, and these are next dissolved and washed out in the "hypo" bath, leaving an image in relief of the object photographed, in which the light portions appear as dark and the dark ones as light, hence the word "negative."

The positives are printed from the negatives by placing a sheet of sensitized paper underneath the negative and exposing it to the sunlight. The sunlight acts more forcibly upon that part of the paper underneath the light portions, the darker portions protecting it somewhat. The print is then removed and put in a bath which washes out the salts of the silver not acted upon by the light. It is then "toned" and "fixed," all these operations corresponding with the "development" and "fixing" of the negative.

The photography of the heavens began with the taking of the picture of the moon by Prof. John W. Draper, March, 1840. The camera, fitted to the telescope, has since added enormously to the knowledge of the astronomer. Rays of light from distant stars

too faint to make an impression on the human eye leave a mark upon a photographic plate exposed to them for hours. The delicacy and extreme precision of instruments used for stellar photographs almost pass belief. For an exposure of hours, clock work mechanism must be employed, the motions of the earth calculated, and the whole so accurately timed as to come within a deviation of 1-1000 of an inch. As mechanicians became expert enough to devise a clock that would keep a star image at one fixed point on the photographic plate, strange wonders of the heavens were revealed. Exposures have been made ten succeeding nights aggregating 25 hours, the star being photographed as near the zenith as possible to avoid the difficulties experienced with the refraction of light occurring near the horizon. What appear to the eye through the best telescopes as single stars are often resolved by the camera into double stars, the tails of comets are wonderfully lengthened, the spectrums of stars can be photographed, and the variability of what were supposed to be single stars found to be due to twin stars revolving about and at times eclipsing each other.

CAMERA FOR STEREOSCOPIC WORK.

Our Debt to the Camera. The camera has achieved results as remarkable for the physician as for the astronomer. The infinitesimal life revealed by the microscope has been permanently recorded by the camera, and the illustrations of the text-books of the pathologist, the histologist, and the bacteriologist show how much medical science owes to photography. Society protects itself against the

criminal classes by instituting rogues' galleries in every important city, and the counterfeiter, who, by the aid of photography, issues a fraudulent note, is by a species of poetic justice brought to bay and identified by his photograph on file at police headquarters.

The camera is no less valuable to the geologist, the botanist, or the engineer. A comparatively moderate pressure on a piece of glass will show any alteration of the refrangibility of a ray of polarized light. "The inventor who thinks he has devised a truss or a girder of new efficiency has, therefore, only to construct a model in glass to bring his plan to an inexpensive test. A beam of polarized light sent through the glass will plainly show to the eye, and register in the camera, the distribution and extent of the strain imposed by a moving load." *

Photo-engraving has aided immensely in producing cheaply, well illustrated magazines. Potassium bichromate has the power, when used in a gelatin emulsion, of rendering the gelatin insoluble after it has been acted upon by light. A copper plate can be coated with the thinnest possible film of this emulsion, exposed in a camera, those portions not influenced by the light washed away and the exposed part of the plate etched out with acids, leaving a picture in relief, the raised portions of which take ink and act as printing surfaces.

Half-tone engraving has practically revolutionized one branch of art and made it possible to issue and profitably sell for ten cents a magazine so well illustrated that it could hardly have been produced at any price fifty years ago. In making half-tones, the photograph is taken through two glass plates having closely ruled lines laid crosswise on each other and forming a screen. Screens on which from 80 to 200 lines per inch are ruled are used; the coarser ones for newspaper, the finer for book and magazine work. The lines on the screen are filled with a fine black substance which intercepts the light

* George Iles, "Flame, Electricity, and the Camera."

that comes to the negative and an image is formed having innumerable minute dots over the surface. These dots form raised surfaces which receive the ink and print like an ordinary relief plate, but the dots are so fine and so close that the suggestions of the mind come to the aid of the eye and it accepts the picture as perfectly reproduced.

ROENTGEN X-RAYS.

Probably no other scientific discovery has attracted such universal attention as that of a "New Kind of Rays," announced by Professor W. C. Roentgen of Würzburg, January 4, 1896. The Roentgen rays are developed by an electrical discharge in a high vacuum. Geissler, a physicist of Bonn, about fifty years ago, constructed vacuum tubes, which bear his name, for experiments of this kind. A degree of exhaustion of about two hundredths of an atmosphere was used. A "tube" in the sense here used is any closed glass vessel having two wires sealed into its sides, which are to be used as the electrodes of an electric circuit, and between which the discharge is to take place in the interior of the tube, which has been exhausted before sealing. The electrode by which the current enters the tube is called the *anode*, and the one by which it leaves is the *cathode*. The high tension current required is usually produced by an induction coil. Brilliant and beautiful color effects are produced when the current passes through tubes of various kinds of glass containing various gases. Geissler tubes are used only for these display purposes.

PROF. W. C. ROENTGEN.

Crookes Tubes. About twenty-five years ago William Crookes of England constructed tubes of great variety, some very highly ex-

hausted. The phenomena exhibited by these tubes were so surprising and wonderful that they constituted a new class of phenomena. Tubes made for repeating these experiments are called Crookes tubes. They may be of cylindrical, or spherical, or of odd and fantastic shapes. They are often exhausted to one-millionth of an atmosphere, and in such cases the phenomena differ from those of ordinary gases, as much as those of gases differ from liquids, or liquids from solids.

In a Geissler tube, the gas in the interior glows with a colored light and exhibits beautiful stratifications. As the tube is exhausted more and more the glow decreases in brilliancy, and entirely ceases when the exhaustion is such that only one-millionth of the original air remains. But at this stage the glass itself begins to emit light, and it is then that the tube becomes useful for the purpose of generating the Roentgen rays. The striking peculiarity of the discharge in the high vacuum is that the cathode is the important electrode.

The photographic part of the operation is carried out after the usual manner. There seems to be but little choice between various developing agents. A great amount of detail appears strongly during the development which is lost in the "fixing" process, and in important surgical cases the surgeon should see the plate during the development in order to obtain the full benefit of the experiment. Various developers and fixing agents have been tried to overcome this difficulty, but without success.

Professor Roentgen, experimenting with a Crookes tube, had placed near it a sheet of paper coated on one side with barium-platinum cyanide. Such paper is a fluorescent screen. He noticed that when the tube was so completely covered by black paper that its rays were entirely invisible to the eye, there still passed through it a mysterious energy that could illuminate his sheet of paper two yards or more away. Further experiments showed that these invis-

ible rays were capable of passing through many substances opaque to ordinary light, just as glass, which offers little resistance to light waves, is opaque to electricity. Professor Roentgen continued his experiments and found that when his hand was placed over the screen the flesh was only partially opaque, the bones more nearly so, and the shadow of the skeleton was outlined on the paper. His knowledge of photography enabled him to catch the fleeting image and make public one of the most interesting and far-reaching discoveries of a decade.

How Ordinary Experiments may be Made. A writer has said persons need not be deterred from experimenting with X-rays because of the cost of a Crookes tube, for fairly satisfactory tubes can be made for a few cents by which many interesting phenomena can be studied. "A person having access to an electric lighting circuit can unscrew an ordinary incandescent electric light globe from its socket and set it up on a candlestick resting on a plate of glass to insulate it. Next, cut a piece of aluminum foil about the size of a dollar and with a little shellac fasten it smoothly on the large end of the globe and procure (or make) an induction coil that will give a spark at least three inches long.

"The house current can be used to furnish the current for the primary of the coil. Connect one end of the secondary with the aluminum foil and the other end with the bottom of the globe. Then remove the globe from the candlestick and place it in the house circuit for 15 minutes. The heat from the incandescent filament improves the vacuum in the globe. Next quickly place the globe back on the candlestick and start the primary on the coil. In a short time the globe will commence to produce X-rays and continue to do so for 15 to 20 minutes."

When the X-ray was discovered in 1896 it took 30 minutes to make a radiograph. Now good radiographs can be made in 1-24000

of a second, and in actual practice the time is less than half a minute. Rarely has a new scientific discovery been so quickly utilized for practical work, and it speaks volumes for the alertness of the medical profession that they have at once and with one accord accepted the aid of Roentgen X-rays. With it the beating of the heart can be watched, bullets detected within the skull, and it is a common thing to locate pieces of steel inside the eyeball within $\frac{1}{25}$ of an inch. Broken bones are easily shown and the surgeon is able after he has dressed a fracture to make a radiograph of it and determine whether or not it has been successfully reduced.

The X-ray has several practical uses. It will show the presence of flaws in large steel castings or the difference between a diamond and paste, and is of great practical value in detecting adulterations of numerous drugs and chemicals.

PAPER.

Man traced his first rude drawings on the walls of his cavern or on the bones of the game that he had slain, and numerous other substances were used as mediums for his communications before the white sheet upon which our daily papers are printed was produced. The early Assyrians used clay. Maspero says, in describing the circumstances of a sale of land in Assyria hundreds of years before Christ: "The scribes are provided with several tablets of baked clay, still soft enough to take an impression, yet hard enough for it not to be easily defaced or lost once it has been made. Each scribe takes one of them, which he lays flat in the palm of his left hand, and taking in his right hand a triangular stylus, its point cut like a bezel, commences to write. The marks obtained by gently pressing the instrument upon the clay resemble a corner, or a metal nail. The scribe commences on the left below the upper edge of the tablet, and soon covers both sides of it with remarkable dexterity. The

two scribes engaged by the contracting parties and the one belonging to the judge write the formulas at the same time, for every public deed must be drawn out at least three times. Formerly two copies only were made, and they remained in the hands of the two contracting parties; but sometimes it happened that skillful but dishonest people altered the writing to their own advantage. The Chaldeans invented an ingenious method of preventing frauds of this kind. The tablet once sealed, they covered it with a second layer of clay, upon which they traced an exact copy of the original deed. The latter became inaccessible to the forgers, and if a dispute arose and some alteration was suspected in the visible text, the case tablet was broken before witnesses, and the deed was verified by the edition preserved inside." *

From such clay tablets their libraries were formed. "The books of baked earth are inconvenient to hold, heavy to handle, the characters are not clearly defined against the yellow color of the clay; but, on the other hand, a work cut upon brick and incorporated with it, incurs less danger than a work written in ink upon rolls of papyrus. Fire cannot hurt it, water cannot injure it for a long time, and if it is broken the pieces are still good; provided they are not reduced to powder, they can generally be readjusted and the text deciphered, with the exception of a few letters or some words of a phrase. The inscriptions found in the foundations of the most ancient temples, several of which are twenty or thirty centuries old, are, as a rule, clear and legible, as though they had just left the hands of the scribe who traced them and the potter who baked them. The hymns, magic incantations, lists of kings, annals, hymns composed almost at the commencement of history, thousands of years before the Assyrian empire, although exposed to the accidents of twenty conquests, to the destroying fury of man and the assaults of

* G. Maspero, "Life in Ancient Assyria."

time, have yet resisted them all, and have come down to us intact; this would certainly not have been the case had their authors confided them to the papyrus, like the Egyptian scribes."*

The papyrus used by the ancient Egyptians is responsible for many words in our language. The word "paper" is derived from it, and from the Greek name of the word "byblos" we get our word "bible." The Romans called papyrus "charta" or "carta," from which are derived the English words "chart" and "card." Papyrus continued in use so long that the official papers of the popes were written on it until the twelfth century.

The Ebers papyrus, one of the oldest authentic books, is a treatise on medicine written during the reign of Amenophis I., probably in the sixteenth century B. C. The roll is 79 feet long. Its pages are numbered consecutively, and in the text are found crosses and asterisks referring to footnotes.

The secret of manufacturing papyrus was guarded jealously in Egypt. Under the rule of Alexander the Great it became one of the chief exports, furnished the writing material for the world, multiplied the making of books, and gave a great impetus to learning.

Parchment is said to have been invented because Attalus, a king of Asia Minor, was a great student and collected a library of over 200,000 volumes. Ptolemy Philometer, king of Egypt, became jealous of the library of Attalus, which he knew depended upon Egyptian papyrus for additions to it, so he issued an edict forbidding the export of papyrus. Attalus, under the spur of necessity, finally made a sort of paper out of sheepskin and from improvements in the process parchment was developed.

Papyrus, an African marsh plant growing in sluggish water, is a large reed. The different parts had various uses; the roots being used for fuel, the inside of the stalk for food, and other portions

* G. Maspero, "Life in Ancient Assyria."

made into mats, baskets, and woven fabrics. In paper making, a section of the stem as long as the width of the paper to be made was unrolled and separated into its layers. The edges of the layers were placed together and, possessing a natural glue-like quality, adhered under pressure. When one layer had been formed, a second layer with fibers crossing the first at right angles was laid. By attaching the ends of the sheets together, a roll of any length could be made. The rough edges were trimmed and the whole beaten with a mallet until the desired degree of thinness and smoothness had been reached, when it was placed under a press to drive out the water and give an even surface. The operation was completed by drying in the sun. The perishable nature of papyrus, on which the records of ancient Egypt were written, has rendered the work of the archæologist more difficult.

Substitutes for Papyrus and Parchment. When the demand for writing material became so great that papyrus and parchment could not supply it, many other substitutes were tried. In the British Patent Office there are hundreds of patents for materials for paper making, among which may be found the following: Rags, old paper, cotton, flax, hemp, wool, jute, aloe, banana, bean stalk, cocoanut fiber, clover, hay, heath, hops, husks of grain, leaves, maize, sugar cane, moss, nettles, straw, seaweed, thistles, silk, fur, hair, leather, asbestos, and frog spawn. An old act of the British Parliament required the dead to be buried in woolen clothing to stimulate the woolen industry and save linen for paper making. The Massachusetts General Court in 1776 required the Committee of Safety in each town to appoint an officer to collect rags. Such events plainly show the condition of paper making at the beginning of the nineteenth century.

The Chinese, as usual, are credited with having made paper at a remote age, employing for the purpose the inner bark of the mulberry

tree, rye straw, and rags, reduced to a pulp. From them the discovery passed to the Hindoos, Persians, the Arabs, and the Moors, who carried the art into Spain, whence it gradually spread to other European countries.

Roll Paper. A Frenchman, Louis Roberts, was able about 1799 to make a continuous roll of paper and in recognition of his discovery the French government bestowed on him a prize of 8000 francs. The Fourdrinier brothers of England took up the idea and further developed it and gave their name to the machine that made the production of paper in large quantities possible.

Paper made from Rags. If we trace the course of a bale of rags on its way through the paper mill until it appears as finished paper, we shall find it is emptied into a "thrasher," the inner surface of which is lined with spikes, and containing a drum armed with similar spikes. Here nearly all the dust is shaken out of the rags and they are passed to the sorting room, where all foreign substances are removed. The rags are sorted according to quality and are fed into the "cutter," which reduces them to bits, whence they go to the "devil," to remove any lingering dust. They are then taken up by a belt, which discharges them into "boilers" containing a solution of mixed lime and soda. Here the rags are continuously dissolved, boiled, and leached until, when the boiler is stopped and opened, "their disposition is softened by trouble and their countenance blanched by fear." The pulpy mass is then run through the "engines," machines which completely pulpify and wash it until it is fit for paper making, when it is discharged into a flow-box whence it issues in a thin stream on to an endless belt of wire cloth running over numerous rollers. The belts have two rubber bands on the edges to keep the paper from flowing out at the sides and the floating fibers are made to interweave or unite by continued shaking or lateral motion given to the belt, which tends to interlace the fibers

and get rid of some of the water, and as the water is removed the belt passes under rollers which still further compress the fiber and deliver it to a felt belt where more of the water is pressed out. It is handled with the utmost delicacy, passed between numerous rollers, and is soon able to sustain its own weight. It passes between hollow rollers heated by steam, which press it, finish and dry it.

Wood Pulp. Whoever holds in his hand the daily paper of any great city, probably holds what was once enough wood to make a club of good size. Wood pulp or wood fiber is now one of the most important paper-making materials. *Wood pulp* is produced by mechanical means; *wood fiber* by chemical treatment. To obtain the pulp, the bark and knots are removed and the wood, cut into suitable length, is fed into a grinding machine, where a huge grindstone tears the wood to bits and the fiber, mixed with water, is carried away on a wire screen, gathered, partly dried, and shipped to paper mills, where it undergoes the usual processes of "beating," etc. Wood pulp can be made directly into wood pulp board, but for thin paper or where strength is required it must be mixed with something having a longer fiber. It can be produced very cheaply.

Wood fiber, or chemical fiber, is produced by two methods: the alkali or soda, and the acid processes. In either case the wood runs through machines which cut it into fine chips, whence it is carried to digesters (boilers) containing chemical solutions to extract the gum. Here it is subjected to considerable steam pressure and is cooked from 8 to 72 hours, the alkali or soda process being the quicker.

In the alkali process, caustic soda is used and the cooking kept up in the digester under a steam pressure of 90 to 100 pounds from 8 to 10 hours. The caustic soda removes the gums and resins and leaves a fiber which when washed and bleached is almost pure cellulose, resembling cotton and having a fair degree of strength.

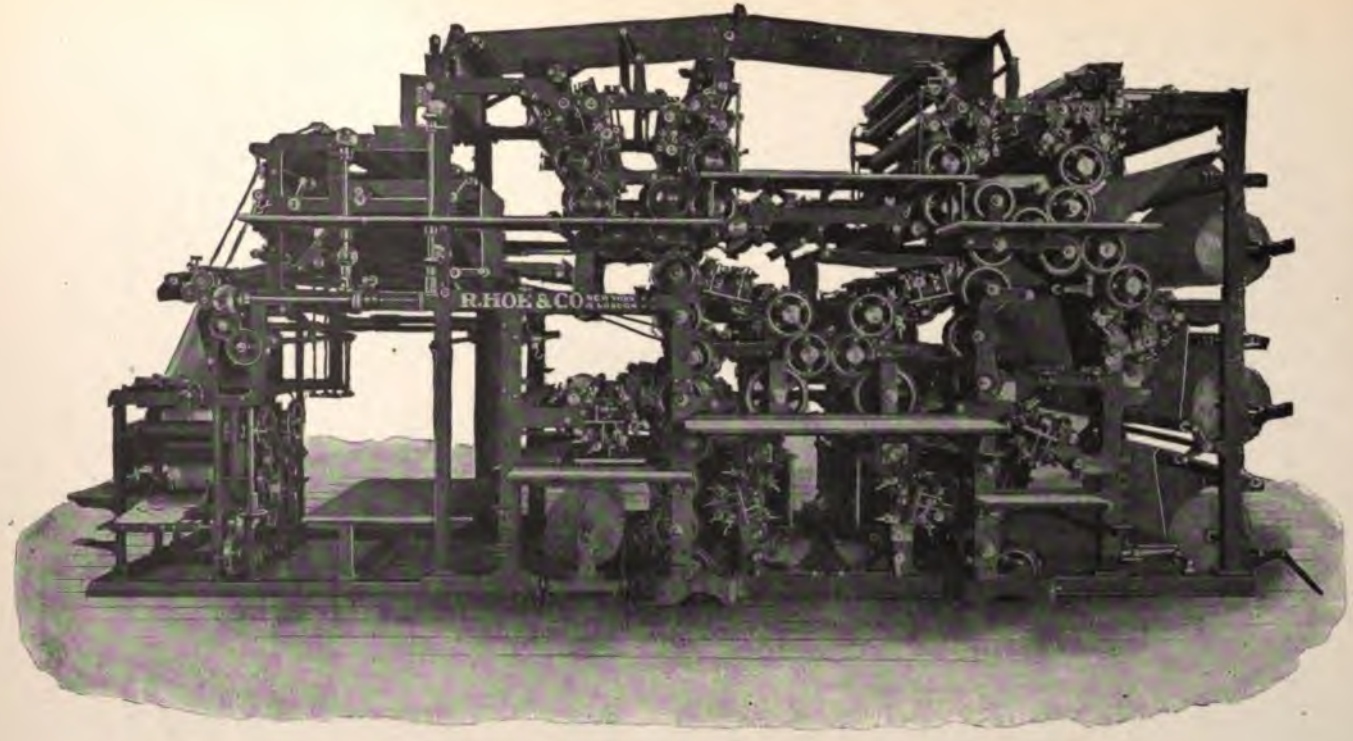
In the acid process the prepared wood is boiled in a solution of

bisulphate of lime, which is so corrosive that the digesters have to be lined with lead, glazed bricks, or some other acid-resisting coating to protect the steel shell of the boiler. Under a high pressure about 16 hours of cooking will suffice; with the lower pressures the process may occupy three days and the resulting fiber is light brown, perhaps with a pinkish tinge and sometimes harsh, but usually nearly white. When cooked and bleached the fiber is soft, of good color, and strong.

Paper making has increased enormously within the past decade, due largely to the development of the wood pulp industry, for the greater part of the paper now produced is manufactured from wood. Germany apparently holds the record for quick work. It is said that the trees from which the wood pulp was made were standing in the forest at 7.35 A. M., and cut, delivered at the paper mill, made into paper, delivered at the printing office, and appeared as printed sheets containing the news of the day at 10 A. M. The Philadelphia *Record* made a trial in 1891 and issued a paper within 22 hours from the time the trees were cut. The performance is marvelous enough that in a few hours converts a forest tree into a black and white sheet covered with the news of the world, containing perhaps a record of events that transpired on the opposite side of the world while the woodcutter's ax was eating its way to the heart of the tree, for such news can be flashed by cable faster than a nerve can convey the sense of pain, and, if received a few minutes before going to press, arrives in ample time, a strange ending for perhaps one hundred years of quiet forest growth.

PRINTING.

The sextuple printing press, capable of turning out more than a thousand papers a minute, is a splendid tribute to the constructive imagination that has raised man from the depths of barbarism. The



THE VERY LATEST IN THE WAY OF PRINTING PRESSES.

This press was made by R. Hoe & Co. and recently installed in the New York *Journal* plant. It will print, cut, fold, count, and deliver 288,000 eight page newspapers in one hour. This is at the rate of 80 completed papers per second.

art of writing dates back to a very early age. A description of the Babylonian expedition to Nippur says, "Writing on clay tablets was practiced in Babylonia long before the time of Lugal-zaggisi, it may be as early as 5000 or even 6000 years B. C."*

The Assyrians, as early as Sargon (3800 B. C.), were using a rude form of type to impress characters on bricks used for temples. Later small cylinders, finely engraved, were used for seals, and, when rolled over a plastic clay tablet, left their impress there, the first rude prototype of the cylinder press.

The Chinese were printing from type as early as 50 B. C., but their language is not well adapted to the use of movable type, for their words cannot be resolved into separate elements like the alphabet of Western nations. The Greeks and Romans were early acquainted with engraved dies and stamping on metal.

About the last of the twelfth or the beginning of the thirteenth century, wood engraving appeared in Europe. The method was to engrave a page of a book on a block and print from it. Separate letters were sometimes engraved, especially initial letters and pictures, and books are in existence having such initial letters and pictures printed while the body of the text is in handwriting. But just as America was named after a man who had more to do with talking about it than discovering it, or as others prominently connected with certain projects have become in the popular mind so identified with them as to be deemed the originators or inventors thereof, so the name of Gutenberg has become associated with the art of printing with movable type.

Gutenberg's Press. The first book printed by Gutenberg from movable type was completed about the year 1450, and a simpler method can scarcely be imagined. His printing press consisted of two upright timbers, with crosspieces of wood to stay them together at the top and

* John Punnett Peters. "Nippur."

bottom, with intermediate cross timbers, one supporting the flat bed on which the type was placed, while through another the wooden screw passed, the lower point resting on the center of the wooden "platen," which was thus screwed down upon the type. After inking the form with a ball of leather stuffed with wool, the printer spread the paper over it, laying a piece of blanket upon the paper to soften the impression of the platen and remove inequalities.

OLD WOODEN FRAME ADAMS BOOK PRESS.

Such was the press of Gutenberg, using the familiar mechanical principle found in the old cheese and linen presses ordinarily seen in the houses of mediæval times. Were Gutenberg to print his Bible to-day, he would find virtually the same type ready for his purpose as that made by him, but he would be bewildered in the maze of printing machinery.

The simple form of wooden press, worked with a screw by means of a movable bar, continued in use until the early part of the seventeenth century without any material change. William Jensen Blaew, a printer of Amsterdam, about 1620, passed the spindle of the screw through a square block guided in a wooden frame, and from this block the platen was suspended by wire or cords, the block or box preventing any twist in the platen and insuring a more equal motion to the screw. He also devised rollers for moving in and out the bed, and a hand lever for turning the screw. Blaew's press was used in England and throughout the continent, being substantially the same as that Benjamin Franklin worked upon as a journeyman in London early in the eighteenth century.

About the year 1798, the Earl of Stanhope made a press with a cast iron frame. He also added a combination of levers which enabled the pressman to give power to the impression, with less expenditure of energy. The presses were heavy and cumbersome but the combination of levers came into general use.

The "Columbian" Press. George Clymer, of Philadelphia, about 1816 devised an iron machine entirely dispensing with screws. His invention, introduced to some extent in England, was known as the "Columbian" press. In 1822 an American, Peter Smith, introduced a toggle joint in place of the levers used on the "Columbian" press, but the greatest improvement of this period was made by Samuel Rust of New York, who devised the "Washington" press, which in principle and construction has never been surpassed by any hand printing press. Its bed slides on a track and is run in and out from under the platen, by turning a crank which has belts attached to a pulley upon its shaft. The impression of the platen is given by means of a bent lever acting on a toggle joint, and the platen is lifted by springs on either side. Attached to the bed is a "tympan" frame covered with cloth and standing inclined to receive the sheet

to be printed. Another frame called the "frisket" is attached to the tympan and covered with a sheet of paper, having the parts that would be printed upon cut away, so as to prevent the "chase" and "furniture" from blacking or soiling the sheet. The frisket is turned down over the sheet and tympan, and all are folded down when the impression is taken. Automatic ink rollers were attached to this machine, operated by a weight raised by the pull of the pressman, the descent of the weight drawing the roller over the type and returning it to the inking table while the pressman placed another sheet upon the tympan. Later improvements in the inking apparatus were made by which the distribution of the ink on the rollers was effected by means of steam power. The bed and platen system of printing, up to the middle of the nineteenth century, was the favorite method of printing fine books and cuts.

The first "power" or steam press was made by Daniel Treadwell in 1822; it was later improved by Isaac Adams of Boston in 1830 and by Otis Tufts of the same place in 1834. One thousand sheets per hour is the maximum speed of the largest sizes of this type of press.

Flat Bed Cylinder Press. The credit of actually introducing into use the flat bed cylinder press is due to a Saxon named Friedrich Koenig, who visited England in 1809, and through the assistance of Thomas Bensley, a printer in London, devised a machine which in 1812-1813 was used by him in printing, among other publications, a part of Clarkson's "Life of William Penn." He also devised what has proved, even to this day, to be the best reciprocating motion of the type bed. In 1814 Koenig patented a continuously revolving cylinder press. The part of the periphery of the cylinder not used for giving the impression is slightly reduced in diameter so as to allow the form to return under it freely after giving an impression. He showed designs adapting it for use as a single

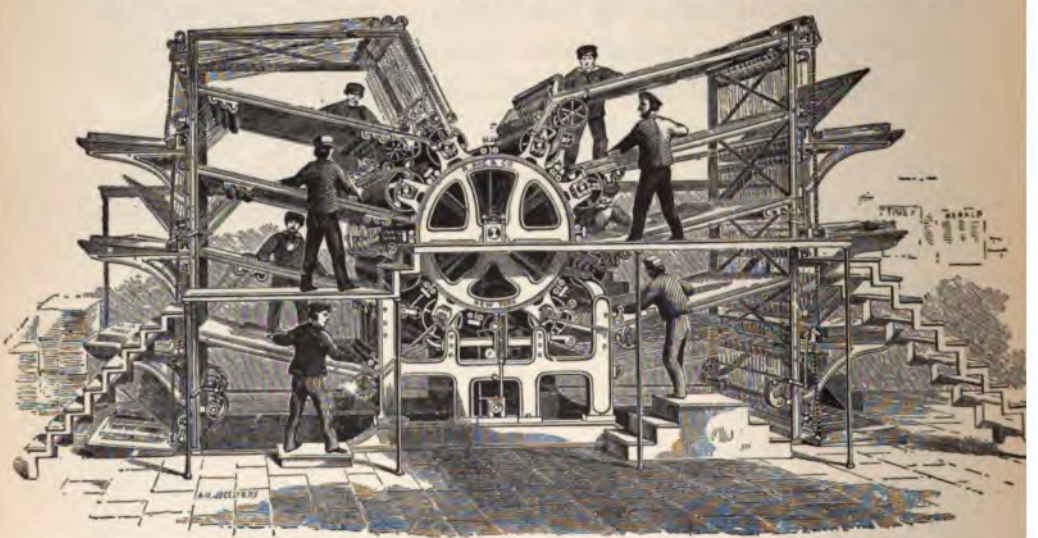
cylinder press and also a two-cylinder press, both for printing one side of the paper at a time; likewise a two-cylinder press for printing both sides of the paper at one operation. This press is termed the "perfecting" press, one of which was placed in the office of the London *Times* in 1814 and which printed one side of the paper only, at the rate of 800 sheets per hour.

The first cylinder press used in the United States was made by Hoe and Co. It was of the pattern known as the "Single Large Cylinder," the whole circumference of the cylinder representing the total travel of the bed, backward and forward, the cylinder making one revolution for each impression in printing and never stopping.

Stop Cylinder Press. The press of the present day upon which the finest letter press and woodcut work is turned off was devised and patented by a Frenchman named Dutartre in 1852, and is known as the "Stop Cylinder." The type is fastened to an iron bed, which moves back and forth upon friction rollers of steel, the bed being driven by a simple crank motion, stopping or starting it without noise or jar. All the wearing parts are made of finely tempered steel. The cylinder is stopped and started by a cam motion pending the backward travel of the bed, and during the interval of rest the sheet is fed down against the guides, and the grippers closed upon it before the cylinder starts, thus insuring the utmost accuracy of register. After the impression the sheet is transferred to a skeleton cylinder, also containing grippers, which receives and delivers it over fine cords upon the sheet flyer, which in turn deposits it upon the table. The distribution of the ink is effected partially by a vibrating polished steel cylinder, and partly upon a flat table at the end of the traveling bed, the number of inking rollers varying from four to six. This is considered the most perfect flat bed cylinder printing machine that has ever been devised. It is made in various

sizes and is capable of one thousand to fifteen hundred impressions per hour. The very finest engravings or cut work is printed upon it at a speed of 700 impressions per hour. This press is used chiefly for book work.

Hoe Type Revolving Machine. To meet the increased requirements of newspapers in America there resulted the construction of a press known as the "Hoe Type Revolving Machine." The



8–Cylinder Revolving Hoe Press.

distinguishing feature of this press is an apparatus for fastening the forms of type to the central cylinder, placed in a *horizontal* position. This is accomplished by the construction of cast iron beds, one for each page of the newspaper. The column rules are V-shaped; *i. e.*, tapering toward the feet of the type. The type on these beds can be held firmly in position, the surface made to form a true circle and the cylinder revolved at any speed required without danger of the type falling out. Around this central type cylinder, from four to ten impression cylinders are grouped according to the output required. The sheets are fed by boys, and taken from the feed board

by automatic grippers. Composition rollers, placed between each of the impression cylinders, ink the type cylinder. The first of these presses had only four impression cylinders, and the running speed obtained was about 2000 sheets to each feeder, per hour, thus giving with a four-cylinder machine a running capacity of 8000 papers per hour, printed on one side, but in the case of a ten-cylinder machine, an aggregate of 20,000 papers per hour. Newspaper printing was revolutionized; journals, before limited by their inability to furnish papers, rapidly increased their issue and many new ones started. The new press was adopted not only on the American continent but also in Europe.

Meanwhile stereotyping was keeping pace with the development of the press, and soon stereotype plates were cast on curves to fit the cylinders and were used in place of type forms. This allowed the duplication of the forms, the running of several machines at a time, and resulted in turning out papers with extra rapidity.

Improvements in Paper and Folding. For four hundred years after Gutenberg little improvement had been made, but now new methods and inventions were introduced with such rapidity that they can only be mentioned and not described. The profitable production of straw and wood fiber added a wonderful impetus to printing, and presses were devised to use with still greater speed the increased supply of raw material. A folding machine was patented in 1875 by Stephen D. Tucker that folded the newspapers as fast as they came from the press. Constant improvements in presses were made and when the "quadruple newspaper press" was constructed and placed in the office of the New York *World* in 1887 it was thought that the limit of printing capacity in one machine had been reached, for it printed 48,000 8-page papers an hour, cut the top, and pasted and folded them ready to be mailed. But the demand for printing seems to increase with the supply, and two years later a "sextuple" press was turned

out for the New York *Herald*, which that paper pronounces nothing less than a miracle of mechanism. It is fed from three rolls of paper and can print and fold 90,000 4-page *Heralds* in an hour, each copy containing an epitome of the news of the world for the preceding 24 hours.

The "octuple" press succeeded that, which prints 96,000 4, 6, or 8-page papers an hour, or at the rate of 1600 a minute, and cuts, pastes, folds, and counts them as fast as printed. Running at its highest speed — so fast that only one fifth of a second is required to print a page — this press will consume in an hour a roll of ordinary newspaper 50 miles in length. In other words, the paper must move as fast as an express train. Picture the amazement of Benjamin Franklin could he be recalled and placed face to face with such a press, and measure the gap that exists between this latest product of the nineteenth century and the rude scrawls traced by the first primitive artist on the walls of his cavern.

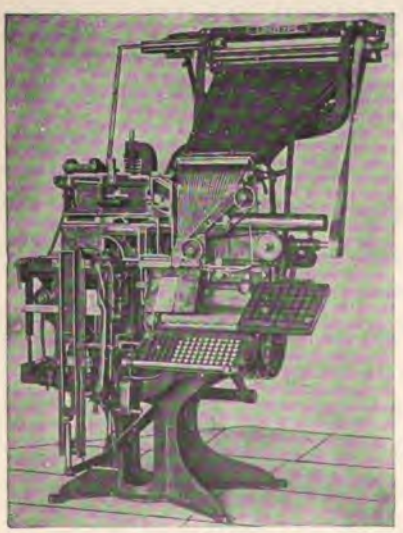
Three color printing has so many difficulties, financial, mechanical, and chemical connected with it, that it has but lately been brought to the stage where it could be made profitable for the printer. A fortune awaits the man who can invent an ink with a strong color and yet transparent enough to let the color from a previous impression shine through and enable the printer to blend them into exactly the shade he desires. For three color printing, three glass screens, a yellow, a red, and a violet-blue, together with a camera that can take three negatives at once, are used. One screen is placed before each photographic plate and of course keeps out all the light except that which corresponds to its own color. From these three negatives, three printing plates are made in the usual manner, and each plate is inked with an ink of the same color as the screen that was used before it. One impression is taken, the paper allowed to dry, then another applied directly over the first so that

every part corresponds to the minutest detail, it is again dried and the third plate used in the same manner. It is plain then that each plate prints its particular color in the places and in the same degree in which that color entered into the formation of the picture. If a red be printed on top of a yellow, the yellow shines through and an orange effect is produced. Blue printed on top of red gives purple, and when all three colors are superimposed a neutral black is produced. All that is needed to make it perfect is an ink that will not mix with the other inks and still be transparent enough to allow the underlying colors to shine through. Some inks have been produced that give very good results, and there have been several books with colored plates recently issued, notably Dr. Holland's "Butterfly Book," in which especially fine work has been done. There are yet many difficult problems to be solved before colored printing can become widely used, but the rough plans have been drawn and the new century will without doubt work out the details.

Typesetting Machines. The wonderful machines just described would be shorn of much of their power if they were not supplemented by typesetting machines. Few who look upon a printed page realize the intricate process and amount of work required to produce it. Every letter, punctuation mark, and space is represented by a type, and the spaces are sometimes made up of several types. For the proper placing of each one of these a compositor has the following distinct operations to perform. He must pick up the type from a chaotic heap in the box allotted to it. He must see that it is the right one and not some other type placed there by mistake. He must turn it so it will be right end up and right side foremost. He must place it in the "composing stick" or typeholder in its proper place and order. This he must do with each individual type, and when he has set enough to approximately fill the line he must "justify" or space it so as to exactly fill the space allotted to the

width of the column. After he has set a few lines he must interrupt his work and place the finished lines in the "galley," for the "stick" will hold but two or three inches of the column.

Typesetting machines have dispensed with all this and have been one of the most powerful factors in cheapening and increasing the production of printed matter. The first patent for a typesetting and type-making machine was issued in England in 1822 to Dr. William Church, who claimed a speed for his machine of 75,000 ems an hour, but it did not prove practicable, although many of his devices were afterwards utilized by other inventors. The first practical machine in the United States was that of Clay and Rosenberg, patented in 1842, but it was not favorably received by the printers. Simpler machines were required. A machine invented by Mitchell appeared and was used for a time, but did not come into general use because there was no good "distributer" to go with it.



THE LINOTYPE.

The Linotype Machine. For newspaper working where speed, economy of composition, and facility in "making ready" are of the highest consideration, the "Linotype" machine stands preëminent. This, the invention of Ottmar Mergenthaler of Baltimore, was invented in 1884 and patented in 1885, with several subsequent patents for improvements, and put at work in the office of the New York *Tribune* in 1886 to the great astonishment and alarm of the old-time compositors. It is a most complicated machine, represents the working of many minds, and embodies 1400 patented ideas. It dispenses with both type and typesetters, and casts

a finished line ready for printing. It requires only a pot of melted type metal, and an operator to manipulate a keyboard, to do many times the work of a hand compositor. Although so complicated it is a marvel of mechanical construction, weighs less than a ton, and occupies but little floor space. So efficient is the machine that it is now found in nearly all the offices of the great daily newspapers of the civilized world.

Construction and Mode of Operation. In the body of the machine is a magazine which contains about 1500 brass matrices with which the machine does its work. Enough matrices placed side by side to fill the space of a line form a mold just large enough for the body of the type for a line, having along the edge of the mold characters sunk into the material of the matrix. These matrices are held ready for use, each character in its own compartment, in the magazine at the top of the machine. The machine has a keyboard like a typewriter, with 107 keys, allowing the use of that many characters and requiring as many compartments in the magazine.

The operator presses a key. The matrix which is lowermost in the compartment corresponding to that key is released and slides down a channel from the magazine, right end out and right side up, and lands on a traveling belt which carries it rapidly to a little compartment at the left of the operator, where it is rapidly followed by the other matrices which are necessary to make up the line. The spaces are filled by a combination matrix made up of two wedges, arranged end for end. As the matrices are slid into this collecting compartment, they are in full view of the operator, and, if he touches the wrong key, the matrix can be extracted and the right one inserted in its place. When the line is nearly full, a bell warns the operator to look out for his syllable division. When the line is completed, a touch of a lever presses the space wedge together and automatically "justifies" the line. A touch of another lever sends the

completed line of matrices hurrying away to the molding wheel. Connected with this wheel is a pot of type metal, kept in a molten condition by a Bunsen burner underneath. When the line of matrices is in position on one face of the wheel, a piston-like plunger descends into the pot and forces a jet of molten type metal through a slot in the wheel against the face of the matrices. The metal solidifies into a solid type bar, along the edge of which stand out the raised letters in the position for printing. A turn of the wheel, and this type bar is loosened from the matrix, and automatically trimmed to the exact shape and size required. Then it is delivered to a collecting galley, from which it is taken to make up the form. As the molding wheel completes its revolution, an arm comes down from the top of the machine, seizes the line of matrices and carries it to the top of the machine, placing it on the distributing bar. One end of the matrix is notched in a very peculiar way, each kind of character having its distinguishing notch and one notch which is common to all. The distributing bar has two sets of projections forming longitudinal ridges on one side. One set engages the notches which are common to all the matrices. The other set fits every one of the different sets, 107 in all. On this bar the line of matrices is strung and moved ahead by a worm gear. Soon the line comes to a place in the bar where there is a gap in the ridges. Fifteen or twenty of the matrices may pay no attention to the gap, but then there will come one which deliberately drops out of the procession at that point and goes scurrying down to its place in the magazine, ready for use when it is needed. Soon others drop out, for there are 107 of those gaps, each one of which is a trap for its own particular set of notches and which will not stop any other set; nor will it let the matrix having its set of notches go past. If it tries to do so, the whole machine stops. The distributing bar cannot make a mistake, and the worst it can do is to stop when there is an error threatened. An operator is required

at the keyboard, and all the other work is performed automatically, the power being furnished by any convenient motor. The machine performs its work with a never-failing accuracy so human-like that it seems almost uncanny.

Typesetting machines proper actually set type ready for use instead of setting matrices. Of these the "Empire Typesetting Machine" is one of the best. This machine sets type of any size, all that is necessary being to have them "nicked." The machine is simple; the working parts are few in number, are easy of access, and not likely to get out of order. During the entire operation of composition, justification and transferring the line to the galley, the face of the type is in plain view of the operator, making it easy to correct any errors due to striking the wrong key. It can be quickly adjusted to set lines of any length. The type are held in a magazine at the top of the machine, containing 84 channels, one for each separate character. It has a keyboard of 84 characters, and when a key is touched the corresponding type is released in the magazine and carried downward to a point where they assemble into line, and drops into the line-holder in the exact order in which the keys are pressed. The line-holder moves forward each time like the carriage of a typewriter, leaving space to receive another type. When a word is completed the operator touches a space key and a thin wedge is automatically inserted between the types. When the line-holder is nearly filled, a bell rings notifying the operator to finish the line properly. As soon as the line is set up the operator touches a line-key which automatically brings an empty line-holder into position and starts the automatic mechanism which justifies the other line and transfers it to the galley, these operations requiring no attention whatever on his part.

Typesetting machines have not proved as popular as was at first anticipated. The Empire is fitted with the "McClintock Justifier,"

and its speed is limited only by that of the operator at the keyboard, for the machine has a capacity of 10,000 ems an hour, while the average day's work of a hand compositor is only from 5500 to 6500 ems per day.

After the type have been used they are carried to a separate machine which "distributes" or assorts the different letters. In this machine a page or block of type matter is placed on the galley of the distributer, where it is automatically fed into the assorting mechanism one at a time, the machinery recognizing the different characters, each by its especial "nick" only 1-100 of an inch deep, and distributing it to its proper compartment. The machine works at the rate of 6000 ems an hour without requiring any attention from the attendant except to see that it is supplied with material. The type when distributed fall into trays, which an attendant picks up without disturbing and places in the magazine at the top of the composing machine ready to be used again.

THE EMPIRE TYPESETTER.

The Empire permits the setting by the compositor of the italics, small caps, and peculiar sorts of type occasionally used, and the distributing machine receives these and, recognizing them as something foreign, deposits them in a separate channel.

Stereotyping. Before the invention of stereotypes a book appearing in different editions must be reset for each edition or be kept continually in type with all the attendant risks of error, damage to the type face, and idleness of capital invested in type. About 1725 William Ged, a goldsmith of Edinburgh, invented the plaster process

of stereotyping, and a company was formed in 1731 to exploit it. Two prayer books were printed for the University of Cambridge, but the contract was abandoned because of the crudeness of the process and the hostility the workmen displayed toward the innovation.

Ged brushed over the form, or body of the type, with oil, inclosed the edges in a box-like frame and poured plaster of paris over it, forming a mold corresponding with the face of the type. The mold was next removed and baked in an oven until all the moisture was driven out. It was then used as a mold for molten type metal, the resulting casting having the same face as the body of type from which the mold was made. This method was introduced into America by David Bruce of New York in 1813, and the first work stereotyped was the New Testament, issued in 1814.

The Clay Process next followed. In this, the body of type is locked, the face brushed with benzine or naphtha and covered with a cloth. A layer about one quarter of an inch thick, of ground clay and plaster of paris, is then turned down over the type and an impression taken. The press is then opened, the cloth removed and another and more accurate impression taken. The mold is then removed and hardened by drying and a casting representing the type face secured by pouring the molten type metal into it. By placing the plastic mold in a curved shell, curved plates adapted to the Hoe press can be made.

The Papier-Mache Process, invented by Ganoux in 1829, has supplanted all others and is the process adopted by all large daily papers where cylinder presses are used. If the form is a flat one the face of the type may be slightly oiled, or the face of the paper powdered with French chalk and the plastic sheets of papier-maché laid over the type, covered on the back with a linen cloth, and beaten down with fine wire brushes until a matrix is formed exactly cor-

responding to the face of the type. The matrix is then removed, dried, and used as a mold.

Better and quicker work is done by machinery. A large sheet of thick, unsized paper is covered with a layer of papier-maché paste, over which sheets of tissue paper are laid and carefully rolled smooth by a heavy iron roller. The prepared sheet is then run under a press roll where it receives the impression of the type, is taken to a drying press, held under pressure while it dries, then heated for a few seconds in a hot oven to remove any lingering moisture. It is then placed in a casting box shaped according to the shape of the plates to be made. The box incloses the bottom and three sides. A plate is placed over the face with a space intervening equal to the desired thickness of the stereotype, and the metal poured in at the open end. It is cooled rapidly, removed, and trimmed. By this process curved stereotype plates, accurately fitting the cylinders of a Hoe press, have been made in six minutes.

If the printing were done directly from the face of the type the resulting wear and damage would be no small item; moreover, after being stereotyped, the type can be distributed and used again, saving the locking up of considerable capital in idle type.

TYPEWRITING MACHINES.

The last quarter of the nineteenth century witnessed the development of the typewriter, a machine so unique that it has lightened the labors of men in business, science, education, and theology. "Wherever thought is to be rapidly, legibly, conveniently, and economically expressed the typewriter is supreme."

"In business circles its desirability is assured. Lawyers and journalists cannot do without it. Professional and scientific men realize its worth to them. The author and thinker finds it invaluable. It conserves the most potent kind of energy—that of the brain—by

reducing to a minimum the mechanical labor of writing, and distributing it among all the fingers of both hands. Writer's cramp disappears where it is used. It presents the printed appearance of the work to the mind at once. It is justly called 'the right hand of stenographers,' as they would be crippled without it. It has vastly enhanced their professional opportunities and earnings. It has demonstrated in the plainest way to a multitude of busy men of affairs the value of stenographic labor. It lightens their work, economizes their time, and thereby increases their ability to personally attend to matters of greater importance. They no longer need to give personal attention to every detail of their correspondence. The transmission of intelligence by telegraph has been revolutionized by its aid. Operators no longer fear 'pen paralysis,' and can perform more work with less fatigue, and at a greater speed than heretofore.

"To educators it offers one of the most valuable assistants in the training of pupils that has yet been discovered. The development of the art of expression is no longer hindered by the difficulty of learning to write. By its aid, the learning of composition, spelling, grammar, punctuation, etc., etc., is rendered easy, and the neat and orderly appearance of the work has a reflex influence upon the pen writing as well as the mental organization of the scholar. Its field of usefulness is unlimited."

First Experiments. The first record of anything approaching the typewriter is a patent granted to Henry Mills in 1714 for "An *Official Machine* or *Method* for the *Impressing* or *Transcribing Letters Singly* or *Progressively* one after another as in *Writing*," but the machine was not perfected and only meager details have survived.

The first patent for an American typewriter was granted William Austin Burt of Detroit in 1829, but Mr. Burt is better known as the inventor of the solar compass, for his typewriter was not completed.

The Burt machine consisted essentially of a segment on which were the letters of the alphabet. A Burt machine could write very slowly.

In 1833 a patent was granted to Xavier Progrin of Marseilles for a typewriter with separate keys by which it was hoped to write "almost as rapidly as one could work with an ordinary pencil." This employed a circle of type bars striking downward to a common center. It had no keyboard and the bars were moved by upright rods passing up through the top plate. His machine was too slow to be of any practical use.

The telegraph gave considerable impetus to researches along the line of writing machines and in 1841 a patent was issued to Thomas Wright and Alexander Bain for a device containing some of the principles of the modern typewriter, but Bain did not attempt to make the machine practical and devoted himself instead to the printing telegraph with which his name is associated. Bain's machine was operated by electro-magnets.

Thurber's Patent. The first practical typewriter was invented by Charles Thurber of Worcester, Massachusetts, and patented in 1843. It was slow and crude but had all the essential characteristics of the modern machine. He was the first to place the paper on a roller and give it a longitudinal motion with provision for accurate letter and word spacing. A horizontal wheel carried on its outer edge rods to the lower end of which were affixed type and to the upper end a finger key. The wheel was turned to bring the type into place and in turning inked the type by drawing the type-face over inked rollers. When the finger key was pressed it forced the type on the lower end of the rod against the paper on the cylinder or platen and printed. Thurber's machine was never manufactured and a museum at Worcester contains the only model in existence.

The next marked development was the work of a blind man, Pierre Foucalt, an instructor of the Paris Institute for the Blind. It

was patented in 1849 and printed raised letters for the use of the blind. It provided for line and letter spacing and the inventor tried to adapt it to ordinary work by the use of carbon paper. It was exhibited at the World's Fair in London in 1851, excited considerable attention, and was awarded a gold medal, though it does not seem to have been used to any considerable extent.

The late A. E. Beach of New York, an editor of the *Scientific American*, was the inventor of a typewriting machine which contained many good features, but was slow in its operation, although in its practical working it closely resembles some of the modern machines. The Beach machine printed only on strips of paper, not on sheets. This machine received a gold medal at the Crystal Palace Exhibition in 1856.

The Remington Machine. Several other machines now followed in close order, but the most important work in the field was done by C. Latham Sholes, a printer and editor of Milwaukee, Wisconsin, who had associated with him, S. W. Soule, a farmer and inventor, and Carlos Glidden, a man of some means. The first model was completed in 1867 and about 25 machines were made one after another as the result of the joint efforts of all three men. The machine wrote accurately and with considerable speed, but did not wear well. Soule and Glidden became discouraged and dropped out, and Sholes associated himself with James Densmore of Meadville, Pennsylvania, who furnished the money for further experiments. Several patents were issued and, encouraged by Densmore, Sholes continued to work on the machines and make improvements, but was

not able to enlist sufficient capital to have his machines made in shops equipped for work requiring such accuracy, and they did not work smoothly and broke down under strain of actual service. In 1873 a contract was made with the famous gun makers, E. Remington and Sons of Ilion, N. Y., and the machine was called, not by the name of the inventor, but by that of the manufacturer, Remington, who consented to undertake the financial venture in an untried field. The unknown inventor could well afford to sink his identity, for the name "Remington" was a guaranty of good workmanship and good material.

The first Remington machines were placed on the market in 1874. Compared with those of to-day they were rather crude affairs, being able to print only capital letters at a rate of speed but little faster than could be written by hand, but the idea was there and the invention *per se* was completed. The machine was exhibited at the Centennial in 1876 and attracted considerable attention, but until 1882 comparatively few machines had been sold and the business seemed likely to result in a failure, when it was reorganized and, under the management of Wyckoff, Seamans and Benedict, the name "Remington" became so familiar that for years many people considered "typewriter" and "Remington" synonymous terms. The works at Ilion were enlarged until the factory was able to turn out a complete machine every five minutes. The first machine printed only capitals, but by the invention of Crandall and Brooks more than

one letter was put on a type bar and the carriage operated by the shift key gave a backward and forward motion. One company could not long control such a profitable business and soon others were in the field evading existing patents and making improvements, until now a typewriting machine is a matter of personal choice to the operator and any one of a dozen will give excellent service. Among those best known and in order of their appearance are the Remington, Caligraph, Hammond, Crandall, Yost, Smith Premier, Barlock, Densmore, Williams, Underwood, and Wellington.

Manifolding. Copying inks are now made for use in typewriter ribbons and typewriter pads that enable its work to be copied in the ordinary letter press.

Carbon paper is made by treating paper of a light spongy texture with oil in which coloring matter is mixed. If a sheet of carbon is placed between two ordinary sheets of writing paper and the whole put in a machine, the type, while making a direct impression upon the first sheet, strikes upon the back of the carbon and produces an exact copy on the second sheet, and by using thin paper and increasing the number of layers several copies can be made at once.

Special typewriters for different kinds of work are now made. The "Comptometer" and the "Numerograph" are a combination of typewriter and calculating machine used in banks. They write columns of figures and foot up the result in an instant without error. Typewriters can be made that will write shorthand characters or foreign languages, and special attachments enable them to make out bills and do tabulating, while one machine in the market can be used to write on blank books. The speed of a first-class typewriting machine is limited only by the ability of the operator, and many can write more than 100 words a minute from memorized sentences. About half a million typewriters are now in use in the United States alone, and the annual exports of the machine now equal about $2,000,000, and its familiar click is heard in every part of the world.

ADVANCE IN AGRICULTURAL MACHINERY.

Improvements Cheapen the Cost of Food — Ancient Reaping Machine — Evolution of the Modern Reaper — Automatic Binder — Plows — Early Plows and Steam Plows — Methods of Thrashing Grain — Flail — Tread Power — Steam Thrasher — Expense of Old and New Methods — Harvesting — What Labor-Saving Devices Have Made Possible — Dairy Machinery — Grain Storage and Handling — How the World is Fed — Grain Elevators — How Wheat is Sold — Cotton and Cotton Manufacturing — Kinds of Cotton — Eli Whitney's Cotton Gin — What It Did for the Cotton Grower — Textile Machinery — Distaff — Spindle — Spinning Wheel — Inventors of Textile Machinery Combated by Angry Operators—First Cotton Mills in America — Growth of the Cotton Industry.

THE improvement in machinery has not been confined to any one line, but all trades, industries, and occupations have alike felt its magic touch. Agriculture is no exception, and the gap is a wide one that separates Maud Müller and her hand rake from to-day's strong steel-fingered machine drawn by horses.

Every improvement in agricultural machinery that has cheapened the price of bread has been so far-reaching in its effects that no limit can be set to its boundaries. Any reduction in the cost of food means a shortening of the hours of toil, more money for clothing, and more time to give to those things which make life worth living. An increased demand for any article reacts upon all the allied industries which supply the labor or raw materials that enter in any way into the construction of that article.

If Richard Roe is compelled to use 50 per cent. of his labor for food, and improvements in farm machinery cheapen the price of his

"The Man with the Hoe."

food 20 per cent., then he has 10 per cent. of the entire proceeds of his labor which he can devote to the purchase of seeming luxuries. Now Richard Roe represents a large class, and suppose with his surplus he buys so prosaic an article as shoes. This means an increased demand for leather, for more cattle, for the hay to feed them, for the mowing machine with which to cut the hay, for skilled workmen to manufacture the machines, for lumber, iron, and steel, for coal to smelt the ore, and food and clothing for the whole industrial army engaged. True, a reaper takes the place of several laborers in the harvest field, but see what a chain of industrial forces it sets in operation.

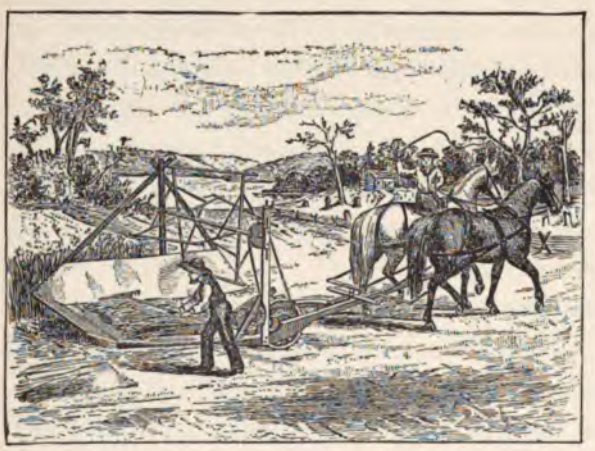
The policies of colonization adopted by the governments of Canada and the United States rapidly brought into cultivation vast areas of virgin soil particularly well adapted to labor-saving machinery and offered a wonderful stimulus to invention. The widespread use of steam power and increased manufactures in turn stimulated agricultural production to supply raw materials, and seeders, harvesters, self-binders, gang plows, steam thrashers, mowing machines, hay rakes, and cultivators have taken many a back ache out of farm work and rendered it possible for one man to perform the work which only a generation ago required twenty.

The first reaping machine is that described by the elder Pliny, 23 A. D., who says, "In the vast dominions of the Province of Gaul a large hollow frame, armed with comb-like teeth and supported on two wheels, is driven through the standing grain, the beasts being yoked behind it, the result being that the ears are torn off and fall within the frame." One would not expect this rude contrivance to survive, but the same device (header) only elaborated is found at work to-day in the western wheat fields of the United States, the Dominion of Canada, and the plains of Australia.

The first reaping machine of modern times is that patented

by Pitt of England in 1786, who attached combs to a revolving cylinder and geared the cylinder to the wheels on which the machine rolled over the field, tearing off the heads of the grain as it was driven through. Rev. Patrick Bell, of Scotland, in 1828–1829, built a reaping machine having a reel, but employing shears to cut the grain. The reel has survived. Various improvements were made in England from time to time, but the harvest fields of the United States and Canada were yet full of the stumps of the virgin forest.

Machines of Hussy and McCormick. The first practically efficient reapers were those of Obed Hussy of Maryland and Cyrus H. McCormick of Virginia which appeared in the early thirties. Hussy's patent was obtained December 31, 1833, and embodied the now familiar cutter bar playing between double guard fingers. It was drawn by horses hitched in front, had a side cut and a platform on which the operator stood who raked off the grain. The McCormick reaper, patented June 21, 1834, had two cutter bars working in opposite directions to each other and was pushed ahead by the team, although, in the description of its patent, McCormick said that one cutter bar could be used, and the team attached at the front of the machine. Although not patented until 1834, McCormick's machine



McCormick's First Harvester.

was successfully tried in 1831. It contained V-shaped knives arranged on a cutter bar moving back and forth through finger guards, a platform on which the grain fell, a reel to hold the grain against the knives while cutting, and a projecting hand or divider which ran ahead and separated the grain to be cut from that left standing. A workman walked behind the machine and with a hand rake drew off the grain from the platform and made it into bundles. The team was attached ahead of the machine and was guided by a boy riding the "near" horse. McCormick's and Hussy's machines were practicable and from the first were successful. They were greatly improved, displayed at the World's Fair in London in 1851 and placed in competition, although Mr. Hussy was not present. The judges awarded the premium to the McCormick machine and declared that it was worth to the people of England as much as the exposition had cost. But at a subsequent trial that year before another jury, Mr. Hussy was present, exhibited his machine and obtained the award over that of McCormick, and at the close of the competition the Prince of Wales ordered two of Hussy's machines.

Later Improvements. Various improvements followed thick and fast. Hussy patented the open-finger guard now so generally used on mowers and reapers. In 1851 W. H. Seymour substituted for the heavy platform the now familiar one shaped like the quarter section of a circle and added a self-raker. The single arm vibratory rake appeared about 1855, invented by Samuel Johnson of Brockport, N. Y. Improvements in machinery for the working of iron and steel made possible the lightening of weight and the consequent cheapening and improvement of the reaper until the present machine drawn by a pair of horses can easily cut and throw off into gavels to be bound by the workmen from eight to twelve acres of grain per day.

The Automatic Binder. The reaper took the place of four or

five laborers armed with cradles, and the next demand was for a binder that would do away with hand labor. John E. Heath of Ohio, to whom a patent was granted July 22, 1854, for binding sheaves with cord, is the pioneer in this line. Other patents were soon issued to other inventors, for to tie a knot in a stretched string was a hard problem. Wire was substituted for cord but its use proved objectionable. It got into the grain when thrashed and magnets were necessary at the flouring mills to separate the iron from the wheat. Cattle were injured by swallowing pieces of wire while eating the straw, and the inventors turned once more to the problem of the stretched string. Jacob Behel solved it and obtained a patent February 16, 1864, for a knotting apparatus that looped the cord and formed a knot, while a cord-holder retained the end of the twine. Several patents were issued and many applications for patents were made, but it remained for Marquis L. Gorham of Illinois to take out, February 9, 1875, a patent for a thoroughly successful automatic twine binder, and John F. Appleby improved upon it February 18, 1879.

The automatic self-binding reaper will cut the grain, bind it, carry the bundles, and deposit them in a heap ready for the workmen to set up into shocks. To-day with one binder and fresh relays of horses it can cut 20 acres of wheat in a day.

Although in the United States only 28 patents were granted on reapers and mowers prior to 1835, more than 20,000 have been granted since, for the reaping machine combines the contributions of many ingenious minds. The reaper and mower are now highly specialized machines, being adapted to the climate, the soil, the extent of the fields, the crops, and with especial reference to whether the harvest fields are found on the hillside or on the plain.

In 1840 there were only three reapers manufactured in the Western Hemisphere. At the end of another decade 3000 had been

made and now about $20,000,000 worth are being made and sold annually in the United States alone, and in 1900 there were exported about $10,000,000 worth to aid in harvesting the crops of the wheat fields of South America, Australia, Europe, Africa, in fact every civilized country in the world where wheat is grown. Two establishments in Chicago alone employ 10,000 men in the manufacture and sale of their machines. Three million five hundred thousand McCormick reapers and harvesters have been made and sold, an equivalent to putting in the harvest field 15,000,000 workers who were not consumers and whose sole task was to harvest the crop and help lower the price of bread.

Tribute to McCormick. In 1878 the French Academy of Sciences bestowed a medal on Cyrus H. McCormick and elected him a member of that famous body in recognition of his "having done more for the cause of agriculture than any other living man."

Plows used as implements for breaking up the soil were known at a very early age. Certain passages of the Old Testament show that at that time the shares were shod with some kind of metal, and plows of some variety mounted on wheels were used by the early Greeks. The modern plow with its curved moldboard to turn over the soil was invented and used in Holland some time during the seventeenth century, and the first steam plow appeared in England in 1832.

Steam Plow. The extent to which steam power is now employed for the purpose of the farm is another marked feature in the recent progress of agriculture. On next page is shown the picture of a modern steam plow at work. This cut does not do the engine justice for, under favorable conditions, it can draw 25 plows at a rate of three miles per hour, plowing the soil much deeper than is ordinarily done by means of horses. Let us see what it costs a day to run this great labor-saving machine:—

One engineer	$3.50
Fireman	2.50
Man to drive water wagon	1.50
Two horses and wagon	1.00
Feed for horses	.50
Sharpening plows	2.00
Oil for engine	.25
One and one half tons soft coal	8.50
Total cash outlay	$19.75

The foregoing estimate is for work on the Pacific coast, where wages are high and coal expensive. The cost would be less in these respects in the middle West.

BEST'S TRACTION ENGINE.—It will do the work of 100 horses.

When we consider that it costs the Eastern farmer from two to three dollars per acre to do with horses what this engine will do for from 25 to 30 cents, we can understand some of the difficulties he

has in competing with the rich grain growing fields of the West. Furthermore, the engine will do the work of one hundred horses and when not at work isn't "eating its head off." But plowing is not the only thing it will do. Equipped with harrows, it will harrow from 100 to 125 acres per day; or attached to a steam harvester will cut, thrash, clean, and put in sacks, ready for market, 1000 sacks of grain per day at a cost of less than 50 cents per acre. By an ingenious contrivance, the machine is made to use as fuel the straw from the grain it thrashes. The small farmer who at thrashing time hires a comparatively large force of men or "changes work" with his neighbor, pays more than this for the use of the thrashing machine alone.

Thrashing Machines. The earliest method of separating grain from the straw was probably that of treading it under the feet of horses and cattle. The familiar injunction, "Thou shalt not muzzle the ox when he treadeth out the corn," certainly proves the method to have been a very ancient one. Two men and four horses, under the most favorable conditions, can thrash 50 or perhaps 100 bushels per day. Another primitive method, that of beating out the grain with the "flail," is even now used where only small quantities of grain are to be thrashed.

The flail is an implement consisting of a great staff about 5 feet long having at one end a "swingle" which is shorter, thicker, and heavier than the staff. The staff is made of some light, strong wood, and the swingle of some tough heavy wood, preferably hickory or oak. A bow and a looped thong of some tough leather, such as eel-skin, connects the two. The sheaves of wheat to be thrashed are laid on the floor with heads overlapping and a workman with the flail beats out the grain. It then has to be run through a fanning mill to separate the chaff. Ten bushels of wheat being a fair day's work for a man with a flail, if the crop were of any great size it

might easily take the greater part of the winter for the owner to thrash it.

Both these methods could be carried on only in clear dry weather, and dampness and rain put an end to thrashing, for the grain became so tough it could not be shelled. It was impossible for the farmer to thrash out his grain in time to carry it to market while the roads were good, or to take advantage of early prices, and these methods continued in vogue until a comparatively recent time, for the thrashing machine is practically the product of the last half century.

Many demands were made for improvement upon the flail, and in 1786 a Scotchman, Andrew Meikle, invented a thrashing machine which consisted of a revolving drum about which were several rollers. Taking a lesson from the dressing of flax, he attached "scutches" to the drum and beat out the grain, throwing grain, chaff, and straw in a heap together, but he afterward added a winnower and had a fairly efficient machine capable of being turned by horse power or steam power, but the machine cost £150 easily, equal in purchasing power to $2250 to-day.

So long as the comparatively small farms of Eastern United States and Canada did not produce much more grain than was required for home consumption the primitive methods sufficed. Not so when the great wheat fields of the West were opened up to cultivation; then a cylinder armed with spiked teeth, revolving within a section of a drum fitted with similar spikes, was invented. Horses attached to long sweeps furnished the motive power. The sheaves were unbound and fed in head first, and the grain, chaff, and straw came out together and were separated by hand, but shaking screens were added which separated the straw and part of the chaff from the grain, and fanning mills or winnowers soon followed, by which the grain was entirely separated from the chaff and seed of the weeds that usually accompanied it.

The Tread Power machine next appeared. This differed from the other in having a strong endless belt covered with transverse slats and supported at each edge in a strong inclined frame. When a horse was placed upon this inclined belt his weight caused it to slide downward, and his instinctive efforts to move forward kept it continually in motion and supplied the power that moved the machinery. But the first machines were not satisfactory, for if the grain were not fed in steadily the motion ran so high that the horse could not keep up and he was thrown back and frequently injured. A heavy balance wheel and brake were added and overcame the difficulty. This machine was an improvement over the flail but was not equal to the demand of the times, and soon machines of greater capacity driven by from eight to twelve horses attached to long sweeps and moving in a circle were used. But even these could not keep pace with the demand and the steam engine was brought into requisition.

The essential parts of the thrashing machine of to-day are a large hollow iron cylinder, the outer surface of which is armed with strong curved light iron teeth which fit into similar projections in the "concave," which is also armed with teeth. The bundles of grain are fed into the space between the concave and the cylinder, where it is shelled by the teeth, the straw passing out on to long fingers, which toss it about and shake the grain out. An air blast from a revolving fan blows out the chaff, and the clean grain flows in a steady stream from one side of the machine. The straw is carried through to the rear end of the machine and there discharged or taken by a straw-carrier, a belt with transverse slats, up an inclined plane and thrown out upon a stack. One of the latest devices in agricultural machinery substitutes in place of the straw-carrier a long jointed tube 16 or 18 inches in diameter, mounted at the rear of the cylinder. Through this the straw is forced by compressed air furnished by the machine. One

man standing on top of the separator near the rear end can raise or lower the tube, turn it to the right or left, and deliver the straw to any desired point on the stack; in fact, no men at all are required to stack the straw.

Harvesting Then and Now. If we look into the cost of the early methods of harvesting, we find that one hundred years ago grain was cut, as it had been for thousands of years, with the sickle, and the cradle was just coming into use. Furthermore, the sickle as then used was not materially different from that of the days of Boaz and Ruth. Years ago Henry Ward Beecher said, "Fifty years ago there was more back ache in harvesting one acre of wheat than there is to-day in harvesting fifty acres." If this were true in Beecher's time, how much more true is it now that steam has come to lighten the labors of the husbandman! The man with the sickle could cut an acre of wheat in a day; the man with the cradle could cut two acres per day; with a reaper, 10 acres per day; with a header, 25 acres per day; and with the steam harvester, 60 to 70 acres per day. Small wonder that in the days of the sickle many a laboring man's family had but a distant acquaintance with white bread. To such, every advance in agricultural machinery has made possible more and better food for the same amount of labor.

The cost of the different methods of harvesting estimated by an English authority is as follows:—

Done with a sickle.	
Five sickle men at 60c.	$3.00
Two assistants at 40c.	.80
Wastage from weather, etc.	1.15
Cost per acre,	$4.95
Done with a cradle.	
One cradler	$1.20
One assistant	.75
Wastage from weather, etc.	.65
Cost per acre,	$2.60

Done with a binder.	
Two horses	$0.30
One driver	.20
One machine	.10
Twine	.25
Wastage from weather, etc	.40
Cost per acre,	$1.25
By steam harvester, " " "	.50

From this we see that the cradle gained over the sickle $2.35 per acre; the binder over the cradle $1.35 per acre; the steam harvester over the binder 75 cents per acre, and over the primitive method of the sickle, $4.45 per acre; and every time the cost of production has been reduced it has put more bread into the mouths of the hungry.

Labor-saving devices have made it possible to plow the ground, plant the crop, harvest, and deliver the grain at the elevator for less than the cost of harvesting alone fifty years ago. In the wheat fields of the Middle West and Northwest, the work is chiefly performed by horse power, still the value of machinery used there is enormous. At Fargo, North Dakota, alone, $3,000,000 worth is sold every year for use in the wheat fields of the Red River valley. Many farms in that region range from 5000 to 10,000 acres, or even larger, and in working them man labor is reduced to a minimum. The plowing is done with gang plows and the cost is seldom over 65 cents an acre. One man, with a 25-foot harrow, drawn by six horses, can harrow 50 acres a day. Four horses pulling a 12-foot drill can cover 25 miles in a day, thus planting over 37 acres. Wheat growers of that region figure that after the ground is plowed it will cost them from 70 cents to 95 cents per acre to get in the crop. Under ordinary conditions it can be harvested for 45 cents an acre and made ready for the thrashing machine. Then one thrashing machine with thirty men can thrash and deliver at an elevator within a reasonable distance at least 2500 bushels a day.

Less than fifty years ago this grain would have been thrashed by pounding it out by hand with a flail or treading it out under the feet of horses. Under average conditions it now costs the wheat farmer $1.60 per acre to thrash the grain and store it in the elevator.

Under the best methods prevailing in that region to-day, the entire labor cost is about $3.65 per acre, and for twenty years the average on the largest farms of that district has been $5.70 per acre.

Profit and Loss. Now let us calculate the margin of profit for the Red River farmers: To be added to the average labor cost are all unavoidable expenses connected therewith, such as repairs, taxes, cost of seed wheat, interest on capital invested in land and machinery. This makes an additional operating expense of $2.85 per acre. Then, under the best conditions likely to prevail, it will cost the Red River farmer $8.55 per acre, per year. For the past ten years, his wheat has brought him on an average 55 cents per bushel and the average yield of his field has been 19 bushels per acre, making his gross income $10.45 per acre. Deducting from this the $8.55 total operating expense, he is left a margin of only $1.90 per acre. It is only by using improved machinery and conducting the business on a large scale and according to the best methods, that this margin can leave a living profit. It is because these growers produce such enormous quantities that they have such a definite influence in fixing the price of grain. If the small producer finds the margin narrow for him, he may console himself with the thought that those who need it are getting better bread and more of it than they could if the grain were produced at a price highly profitable to him. He will improve his own business prospects by devoting his energies to those lines of farming in which intelligent hand labor plays a large part, avoiding those in which the operations are so large as to profitably employ a large acreage and expensive machinery, and above all will make the most of the peculiarities of his soil and climate and his proximity to large markets.

Dairy Machinery. It is said that the first cheese factory in the United States was that built by Jesse Williams of Oneida county, New York, in 1860. The astonishing growth of the industry is well shown by the report of the Department of Agriculture for 1900, which states that from the milk of 1,000,000 cows, 300,000,000 pounds of cheese were made, having a value of $27,000,000—not a bad showing for an industry only forty years old. It is estimated that there are 17,500,000 milch cows in the United States, and the annual value of the dairy products aggregates $500,000,000. The value of the butter alone is $257,400,000.

It is needless to say that the primitive method of butter-making carried on in the household where the tin pan, the skimmer, and the dash churn were employed could never produce such results, and machinery has revolutionized the dairy industry. In new milk the butter fats, cheese fats, etc., are in the form of minute globules floating in the watery portion of the milk. In the old method of butter-making the milk was placed in pans and the fats, being lighter, rose to the top and, collecting there, formed the "cream." This was skimmed off, put in the churn and there stirred or beaten until the butter fat globules cohered and gathered in a rich yellow mass. All

CENTRIFUGAL MILK SKIMMER.

this consumed much time and required labor not many steps removed from drudgery. In the preceding illustration is shown a centrifugal milk skimmer made by the De Laval Separator Company. Through the lower pipe steam is admitted to a steam turbine in the base of the machine. The milk, freshly drawn from the cows, is turned into a vat and fed into the upper part of the machine. A shaft attached to the turbine at the base of the machine runs into the upper part and terminates in a pan. The milk enters the pan and is rapidly whirled about. The cream with its lighter specific gravity goes to the center and comes out through the upper spout; the heavier milk goes to the outside and issues through the lower spout. The whole operation requires but a minute or two, does away with much work and makes available the fresh skim milk—much better food for calves or pigs than the sour milk of the old process. By the old methods the butter was made in different households and varied in quality according to the skill and neatness of the housewife. Now "butter factories" stationed at convenient points receive the milk from numerous dairies and convert it into butter of a uniform grade and standard quality that meets with a ready sale—so ready, in fact, that the entire product is often sold in advance of its manufacture and at a price relatively 25 per cent. or 50 per cent. higher than could be obtained fifty years ago.

Although numerous patents have been issued for "cow milkers," no manufactured article has yet been produced that could compete with the natural process, and it requires the year around the constant time and entire services of 200,000 able-bodied men to milk the 17,500,000 milch cows of the United States.

GRAIN STORAGE AND HANDLING.

The problem of feeding the world has only just begun when the wheat has been grown. In a few weeks time the grain is harvested

and sold, but after it leaves the place of its birth in the Northwest it takes such a trip as few of its producers realize, and undergoes some very peculiar experiences.

After harvest and until winter sets in, all the railroads reaching the wheat country are busy in carrying the crop to the nearest market; running extra trains, borrowing extra cars, and straining every capacity to the utmost to take care of the crop. Its outrush from the place of its production is rapid but its consumption is continuous and necessitates storing until needed. In the interim speculators are busy with the market but many brokers never see a grain of the wheat. For example, a train load of wheat of a certain quality may be received at Montreal and stored in a great elevator, full details telegraphed to New York and certificates issued to the owners. In an elevator in New York is wheat of a similar quality, perhaps two or three years old. The owner of the Montreal wheat can take advantage of sudden turns in the market by simply presenting his storage certificates at the storehouse in New York, which will issue him a certificate for an equal amount of New York wheat less the necessary charge to cover the cost of storehousing and transportation, and he can sell his New York wheat as though it were the identical wheat stored in Montreal. By this method the transportation of wheat becomes practically instantaneous. All the great elevator systems are organized as thoroughly as the banks, and the transfer of wheat between them adjusts itself in such a manner as to keep the balances even.

Organization Reduces Price. Wheat constantly flows eastward, but the warehouse system prevents unnecessary handling, for it is cheaper to carry a receipt across the country than a million bushels of grain. This simplifying of the transportation really is a saving to the consumer, much as we hear the broker's profits deplored. Of course, the grain is moved, but it makes only one trip to its ultimate

destination, instead of changing hands and places at every transaction. It is the same as the international credit system. Time was when a New York merchant buying goods in London had to send a man and the coin across the ocean. The ship might be wrecked, the money lost, or the agent be dishonest, and in any event valuable time was lost. A system of international credit sprung into being. The American merchant put his money into an American bank, and the English merchant put his in an English bank. The two orders were sent by cable. The goods at once started for their destination and as soon as they were started each merchant could go to the bank and get his money, the whole operation consuming minutes where it had required weeks. The banks simply exchanged the balance of cash that was due either one way or the other.

Although fortunes may be made or lost by the brokers, the wheat is really brought to the consumer at a less cost than would be possible if the old plan of direct exchange of money for goods were to be followed, for this would require a vastly greater number of transportation systems, and the extra cost would have to be borne by the producer and the consumer. The middleman's commissions would increase at every turn, while the farmer would get less and the consumer pay more to make up for the cost of the unnecessary transportation.

Grain elevators are enormous buildings economically constructed for the reception, handling, and storage of grain. They are chiefly located at the ports of the Great Lakes and on the Atlantic seaboard. The old method of handling grain consisted of shoveling into bags the grain in the holds of ships, men carrying the bags on their backs and emptying them in a warehouse, the operation requiring several days. Such crude methods could not long survive, and now machinery will do in an hour what men could not do in a week.

The Silo plan is the latest for grain elevators. The building is

GRAIN ELEVATOR.

made high and the body filled with deep six-sided bins (like a honeycomb) leaving no waste space. Each bin has a slanting bottom and a valve at its lowest point through which it can be discharged through a spout emptying into a waiting ship or car. Beneath the bins are cellars, in which are the engines and part of the conveying machinery. Above the bins is the machinery room, having in the floor openings through which wheat is discharged into the bins. *Elevators* carry the grain up to this floor and *conveyers* take it to the proper opening and discharge it into the bin. When a vessel loaded with grain is brought alongside this monster building, "legs" having within them an elevator are lowered through the hatchway and thousands of tons of grain are moved in a short time. These elevators carry the grain to a tower, where it is cleaned, weighed, sampled, and its quality determined. It is then discharged on to a *conveyer* which takes it to the mouth of the bin prepared for it.

The conveyer is a broad belt, perhaps 18 inches in width, running horizontally and passing at one end over a pulley which applies the power and at the other end over another pulley which keeps a tension on the belt so great that it will not sag. The belt passes over numerous rollers, so arranged as to cause it to "trough" and prevent the grain from spilling over at the side. Such a conveyer can only move the grain *horizontally*. A belt, such as described, running at a speed of 8 feet a second will move 70 tons of grain in an hour. Elevator belts to carry the grain *upward* are fitted with numerous buckets. At the lower end they pass over a bottom pulley and, as they turn right side up, fill themselves with grain. At the upper end of the journey they pass over a top pulley and are turned upside down, the speed with which they turn throwing out the grain into a receptacle provided for it. The belt and bucket elevator can move about 150 tons an hour.

Pneumatic elevators can be made of almost any desired capac-

ity. They are long, flexible, steel tubes made up of numerous joints of tapering tubing and covered by a coat of rubber to render them air tight. A rubber tube would not answer, for the air within the elevator is exhausted until the outside atmospheric pressure exceeds that within by 5 pounds per square inch, enough to collapse a rubber tube, while the friction of the moving particles of grain would soon wear out the rubber. Within the lower end of the tube is a sleeve with a space of about 1½ inches between it and the tube proper. The sleeve extends back about two feet from the nozzle. The nozzle is plunged into a mass of wheat, the air inside the tube is exhausted, and the inrushing air as it passes around the nozzle picks up the grains of wheat that lie in the way and carries them into the tube, and the current is so strong that the grain hurries along out of the hold of the ship over the side of the vessel into the warehouse, and falls into a great receiver, the bottom of which is made into two boxes so arranged that when one is full it turns over and presents an empty one to be filled and does not allow any air to enter the receiver. In turning, each full box deposits its load in the bin of the weighing machine. A tube leads out of the top of the elevator to an engine which exhausts the air and maintains a vacuum within the elevator, 5 pounds below atmospheric pressure. This system requires more power to operate it than the belt and bucket plan, but handles the grain much faster, takes up less room and requires the services of fewer men; one man at the nozzle being all required in the hold of the vessel.

The New Way. A little more than a generation ago if a London merchant wanted wheat, he sent his ship to the Black Sea for it and congratulated himself if the round trip was made in five months and a cargo of 300 tons delivered. To-day he can send his order by cable and within a week a ship can put down at his warehouse a cargo of 14,000 tons of American wheat.

The wheat crop of the world for 1899 was 2,725,407,000 bushels, of which the United States produced 20 per cent.; Russia, 17 per cent.; British India, 8 per cent.; France, 13 per cent.; Hungary, 5 per cent.; Argentina, 3 per cent.; and Canada, 2 per cent. During the year 1900 the United States exported barley, corn, oats, rye, and wheat, ground and unground, amounting to $250,786,080, an amount greater than the whole population of the country could produce in months without the aid of machinery.

COTTON AND COTTON MANUFACTURING.

Cotton is the soft downy fiber clinging to the seeds of several species of plants of the Mallow family. It is a tropical plant but thrives best under cultivation in a temperate climate. In the United States, two species are grown.

Sea-island, long-staple, or black-seeded cotton, as it is variously called, thrives best in a salt atmosphere and is produced chiefly along the coast of South Carolina, Georgia, Florida, and in Egypt. The blossom is of a rich cream color. The fiber is long and silky and commands a good price.

Upland, short staple, or green-seeded cotton, is the kind most widely grown. The flower is a pure white, but turns on the second day to red. These varieties of cotton are annual plants and require for their successful culture, a climate free from frost for six months, with moderate rain during the growing season and dry sunny weather when the plant is coming to maturity. The flowers produce "bolls" containing numerous seeds with the lint or fiber adherent. The fiber contained in a boll weighs about half as much as the seed. The yield in the Southern states ranges from one fourth of a bale of 500 pounds to two bales per acre. If the seed is returned to enrich the soil and nothing but the lint removed and sold, cotton is the least exhaustive of any crop that is extensively cultivated in the United States.

There are other varieties of cotton that are perennials of a larger growth, as tree cotton, but these produce only an inferior fiber and are not of much importance.

The United States produces rather more than 80 per cent. of the cotton of the world. Cotton sold in the United States for 33 cents a pound when Whitney invented the cotton gin (1793). The lowest price in one hundred years was that of 1845, when it sold in New York for five cents per pound. In 1828 sea-island cotton brought $2 a pound, and in 1864 short staple cotton touched $1.89, due to the cotton famine caused by the Civil War. Improved methods of cultivation and the use of commercial fertilizers have greatly improved the staple and increased the production, while the by-products from the seed have helped to pay the cost of growing the crop. All these influences have tended to depress the price. The United States crop of 1899 was the largest known, reaching 11,274,840 bales of about 500 pounds each. The raw cotton exported for the year ending December, 1900, was valued at $314,252,080, being the most important export of the United States, not a bad showing for the industry when we learn that in 1784 eight bags of cotton were seized by the officials at Liverpool on the ground of fraudulent declaration of origin, because it was certain that so much cotton could never have come from America.

The Cotton Gin. It does not often fall to the lot of one person to render mankind two such signal services as did Eli Whitney when he introduced the modern system of interchangeability of machine parts and invented the cotton gin. A character whose inventions have had such widespread influence may merit a short sketch.

Eli Whitney was born December 8, 1765, at Westborough, Mass., and at an early age displayed mechanical genius of a high order. Feeling the need of a liberal education he entered Yale College in the face of many obstacles, in 1789, and completed his college course

in 1792. In the autumn of that year he, as he supposed, was engaged as a teacher in a Georgia family, but on arriving at Savannah he found another teacher had been secured, and accepted the hospitable offer of Mrs. Greene, the widow of General Nathaniel Greene, to make her house his temporary home. His mechanical skill found employment in making toys for the children and some embroidery frames for Mrs. Greene. Soon after his arrival a party of distinguished gentlemen from the upland region came to visit Mrs. Greene and were lamenting the lack of some economical method of separating the lint from the seed of the upland cotton. Removing the seed from one pound of cotton fiber was a day's work for one woman and until a cheaper method could be found cotton could not be profitably raised in the upland regions. Mrs. Greene declared she knew the man who could produce the desired machine and introduced Mr. Whitney to the gentlemen. Although he modestly disclaimed any belief in his ability to solve the problem, he was nevertheless so much interested that he obtained some cotton in the seed and began a series of experiments, although much handicapped for lack of proper materials and tools. Success crowned his efforts.

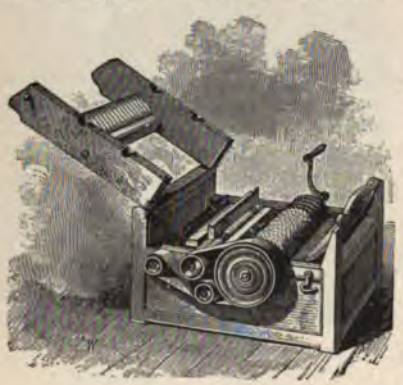
ELI WHITNEY.

Whitney's Application for Patent. Writing November 24, 1793, to Thomas Jefferson, Secretary of State, and making application for a patent, he says:—

"Within about ten days after my first conception of the plan, I made a small, though imperfect, model. Experiments with this

encouraged me to make one on a larger scale, but the extreme difficulty of procuring workmen and proper materials in Georgia prevented my completing the larger one until some time in April last. This, though much larger than my first attempt, is not above one third as large as the machines may be made with convenience. The cylinder is only two feet two inches in length, and six inches in diameter. It is turned by hand, and requires the strength of one man to keep it in constant motion.

"The main features consist of a cylinder, generally about four feet long and five inches in diameter, upon which is set a series of circular saws, about half an inch apart, and projecting about two inches above the surface of the revolving cylinder. A mass of cotton in the seed, separated from the cylinder by steel bars of grating, is brought into contact with the numerous teeth on the cylinder. These teeth catch the cotton while playing between the bars, which allow the lint but not the seed to pass. Underneath the saws is a set of stiff brushes on another cylinder revolving in the opposite direction, which brush from the saw teeth the lint which they have just pulled from the seed. The remaining feature is a revolving fan for producing a current of air to throw the light and downy lint thus liberated to a convenient distance from the revolving saws and brushes."



WHITNEY'S FIRST COTTON GIN.

Whitney's Struggles. Phineas Miller, who afterward married Mrs. Greene, took a great interest in Whitney's machine and formed a co-partnership with him. Whitney went back to Connecticut to establish a shop for the manufacture of the machines and obtain a

patent, but rumors of his wonderful invention had spread until the greatest excitement prevailed, and one night the building in which the model was kept was broken open, the machine stolen, and, before Whitney could obtain his patent, machines with slight changes from the original were in widespread operation. A patent was issued to him in 1794 and suits for infringements were at once begun, but it was almost impossible to find a jury in the cotton region that would render him a verdict in accordance with the facts, and it was only after many years of expensive litigation that Whitney could obtain anything like justice. The United States Court of Georgia, December, 1807, rendered a decision in his favor and the judge said:—

"With regard to the utility of this discovery, the Court would deem it a waste of time to dwell long upon this topic. Is there a man who hears us who has not experienced its utility? The whole interior of the Southern states was languishing, and its inhabitants emigrating for want of some object to engage their attention and employ their industry, when the invention of this machine at once opened views to them, which set the whole country in active motion. From childhood to age it has presented to us a lucrative employment. Individuals who were depressed with poverty and sunk in idleness have suddenly risen to wealth and respectability. Our debts have been paid off. Our capitals have increased, and our lands trebled themselves in value. We cannot express the weight of the obligation which the country owes to this invention. The extent of it cannot now be seen."

A Modern Cotton Gin.

By the time Whitney had secured favorable decisions his patent had nearly expired, and an application made for renewal in 1812 was refused. South Carolina voted to buy the patent right for that state for $50,000. North Carolina laid a tax for five years on cotton gins working within its borders and turned the proceeds over to Whitney after deducting the expense of collection. Tennessee passed an act taxing cotton gins but soon repealed it. The cotton gin brought Whitney fame but little fortune, for the money received was swallowed up in defending his patent. He would have been better off financially had he never invented it but devoted his attention to those other mechanical pursuits where he afterward exhibited such great talent.

The cotton crop of the United States for 1899 amounted to 11,274,840 bales, or about 5,637,420,000 pounds. The seeds were all separated from this by the cotton gin. Had the hand labor method been employed it would have required the services of more than 18,000,000 slave women for 300 working days. A single cotton gin performs the work of thousands of pairs of hands. Does the world owe anything to an inventor who has made possible so great an industry?

Textile Machinery. The person who invented the process of spinning cotton lived so long ago that his name is not recorded in history. Egyptian mummies were wrapped in cloths of the finest linen, though cotton was sometimes employed and was also used for the garments of the priests. The natives of Africa, Asia, and America had mastered the art of making cloth from the fibers of cotton long before the Europeans knew that such a plant as cotton existed.

The distaff and spindle were the instruments used for spinning for centuries. The spindle was at first simply a stick with one end split and the other end held in the hand. A few fibers were twisted

into a cord with the fingers and the end of the cord inserted in the cleft. The distaff was another stick about which the raw material was wrapped. That portion of the fiber between the distaff and spindle was twisted and then wound upon the spindle, a new portion of untwisted fiber unwound from the distaff, and the operation repeated. Although the distaff and spindle were replaced by the spinning wheel during the reign of Henry VIII. of England, yet they were in use in northern Scotland as late as 1817.

The spinning wheel consisted of a horizontal spindle made to revolve rapidly by a band from the large wheel turned by the hand or foot. It is perhaps of Hindoo origin. In the spinning wheel the end of the cord was fastened to the base of the spindle and the "roving" (untwisted fiber) held at such an angle that it would wind about the spindle in spirals out to the end, where it was held while a few turns were given to the hand wheel which revolved the spindle and twisted the thread. The wheel was then stopped, turned back a little, the long spirals unwound, and the finished thread wound on the base of the spindle, the last few inches of it running out in spirals again to the end of the spindle, where the operation was repeated. Such was the spinning wheel of our great-grandmothers and the highest development of the hand power machine, requiring the constant attention of one person to spin one thread. And so rapid has been the progress in textile machinery that the spinning wheel and the hand loom are not yet obsolete.

Thousands of patents have been issued in England and the United States for textile machinery, and among so many space will permit but the briefest mention of a few that have been epoch making in their influence. A strange fatality for many years seemed to accompany them, and Whitney's experience with his cotton gin was no exception to the common fate of inventors of cotton manufacturing machinery.

The spinning jenny was invented by James Hargreaves, of England, in 1763. Hargreaves was a poor weaver with a wife and seven children depending upon him. Brooding at home over his lot one day, the spinning wheel was overturned while in operation and he noticed that it continued to revolve. He seized the "roving" and fed it on the spindle. The spindle did its work in a vertical position. He then made a rude machine consisting of eight vertical spindles set in a frame. The rovings were wound upon "bobbins" and carried through a clasp controlled by the left hand of the operator, thence to the spindles. With his right hand he turned a wheel having a belt running from it that turned all the spindles. He was able to make eight threads within the time formerly required to make one, and improvements raised its efficiency to 120 times that of the spinning wheel. His neighbors, hearing of it, attacked his cottage, smashed the machine, and threatened to kill him if he ever made another. He took out a patent in 1770, but because he had sold some machines before his patent was taken out the title was invalidated and the invention became public property, while Hargreaves struggled on in penury.

The fly shuttle, by which a weaver was able with less labor to double his production, was invented by John Kay in 1733, but everywhere that he tried to put it in operation he found the workmen opposed to him. In his native town a mob broke into his house, destroyed his furniture and barn, and would have killed him had not friends helped to conceal him. He died in France in extreme poverty.

The spinning frame, throstle, or water frame, as it is variously called, was patented by Richard Arkwright in 1769. This was a device for spinning with rollers, the "roving" passing in succession through pairs of rollers; the forward pair had a higher motion than those behind, and so drew out the roving gradually and regularly

and made a smooth, even thread. Deterred by the strong feeling against invention of labor-saving machinery in Lancashire, he went to Nottingham and started a factory on a small scale for the spinning of hosiery yarns, but he had to fight the whole trade and every possible prejudice that could be incited against his machine. The authorities put a double tax on cloth made from the new yarn and he was involved in numerous costly lawsuits in defense of his patents. His buildings were burned, but his improvements enabled him to produce yarn of such a superior quality that he afterward acquired command of the market and was knighted by George III.

It has been stated that Arkwright is improperly credited with the honor of the invention of the water frame and that patents were issued by the English government in 1738 for the same invention to one Lewis Paul, who stated that his partner, John Wyatt, was the true inventor, for whom he, Paul, was acting as attorney.

The spinning mule, invented by Samuel Crompton, in 1779, combines the invention of Arkwright's drawing rolls with the upright spindles of Hargreaves. The spindles are mounted on a carriage that moves back and forth at some distance from the drawing rolls, which are held in a stationary frame. As the carriage travels back and forth it simultaneously twists the thread and draws the rovings, producing threads of great fineness and uniformity, for one of the special features of the machine is the stretching and drawing out of the thicker parts of the thread down to a uniform size. The news of Crompton's machine spreading abroad incited a riot, and his model had to be taken to pieces and hidden away in a garret. When after a time he got one of his machines at work the secret was stolen from him and became public property. He assigned his patent to the manufacturers of Lancashire upon their promise to take up a subscription for him, and the subscription netted him about $300,—for something that added millions of dollars to the wealth of Lancashire.

The government, in tardy recognition of his services, granted him £5000 in 1812, but he was then approaching old age, the money was lost in unfortunate investments, and he was saved from destitution in his last years only by a public subscription.

The power loom was invented in 1785 by the Rev. Edward Cartwright, who also invented a wool-combing machine. "For years he had to abandon his loom because of the threatening attitude of the working people toward it, and his wool-combing inventions cost him so much and were pirated to such an extent that he was brought to the verge of ruin. Parliament in 1809 made him a grant of £10,000, which provided for the comfort of his declining years."

First Mills in America. Prior to 1790 the clothing in America consisted almost entirely of homespun woolen and linen, for cotton and silk were imported luxuries which only a very few could afford. Great Britain's laws for a long time forbade the exportation of machinery or drawings from which the machinery could be made, and for many years the emigration of skilled workmen was prohibited. While these laws were in operation Samuel Slater came from England to America in 1789, disguised as a farm laborer, but bringing in his head the plans of the first *successful* cotton working machinery ever set up in America. Aided by Moses Brown, a Quaker of Providence, Rhode Island, who furnished the money, the first cotton mill in America fitted with Arkwright machinery was built by Slater at Pawtucket, Rhode Island, in 1798.

In a modern cotton mill the cotton from the bale passes through a complicated process before it leaves the loom. It is beaten to divest it of all sand and dirt, then, while finely divided, blown against a wire gauze belt which catches the fibers but allows the dirt to pass through. This operation is repeated until the cotton is thoroughly cleansed. It then passes through the picker, where all foreign substances are removed. It is again finely divided and blown against a

wire belt which carries it to the carding machine. The carding machine is a large broad wheel having its surface thickly set with wire teeth. These catch the layer of cotton as it is fed in at one side and carry it in and over to the opposite side of the machine, but on its way the cotton is subjected to the action of four small rollers armed with wire teeth and revolving in the opposite direction to the large wheel. When the cotton makes its exit from the machine the layer is about $\frac{1}{100}$ as thick as it was when it entered, and all the fibers lie parallel to the long axis of the layer. The layer is then fed into a trumpet-shaped can and literally "comes out of the small end of the horn" as a round, loose, and slightly twisted rope, roll, or roving. As a roving it passes to the drawing frames, which reduce it in size and deliver it to a machine which draws it to the required size and gives it more twist. Issuing from this machine it is called the "finished roving," and is ready for the mule, which imparts to it the final twist and makes it ready for the loom unless a thread is required of two or more strands, in which case it passes through the additional process of ring spinning before it is ready to be woven.

The Growth of the Industry. In 1790 it required five days' work on the part of a slave woman to remove the seed from enough cotton to make a yard of calico, and the only use for the seed was to enrich the soil. To-day the by-products from the seed more than pay the cost of ginning. In 1790 there were only 70 cotton spindles at work in factories in the United States. A hundred years later there were 14,188,103, affording employment to many thousands of operatives and turning out a product valued at $267,981,724. In 1800 the price of a pound of cotton yarn was about $1.25. For the last decade it has ranged from 13½ cents to 18½ cents. Statistics taken at the close of the century show for the last decade an increase of nearly 50 per cent. in the number of spindles and more than 50 per cent. in the number of cotton looms in operation.

MISCELLANEOUS.

OPTICS — Spectroscope and What It Tells of the Constitution of Heavenly Bodies — The Telescope and its Revelations — Refracting and Reflecting Telescopes — Great Telescopes — Microscope and the Wonders It Reveals — What It has done for Civilization — MECHANICAL PROGRESS IN SURGERY — Old Method and the New — Marvelous Surgical Operations — Bacteria — What They are and What They do — Skin Grafting — Surgery in Cancer — Operations on the Eye — Vaccination — HOUSEKEEPERS' DEBT TO INVENTION — Housekeeping a Century ago — Recent Improvements in the Household — Labor-Saving Devices for the Preparation of Food — Sewing Machines — UTILIZATION OF WASTE PRODUCTS — By-Products of the Slaughter House — What Becomes of the Steer — Cotton Seed and its By-Products — Coal Tar and its Marvels — Petroleum and its Derivatives — Blast Furnaces — Coke Furnaces — HOW TO MAKE AND PATENT AN INVENTION — Profitable Inventions — Civilization's Debt to the Inventor — MACHINERY LABOR AND WEALTH — Revolution in the Industrial World — Does Machinery Displace Labor — Inventions Create Occupation — Inventions Increase Production — Relation of Machinery to Wages — Progress Entails Loss to Capital — Machinery Increases Wealth — Civilization's Debt to Machinery.

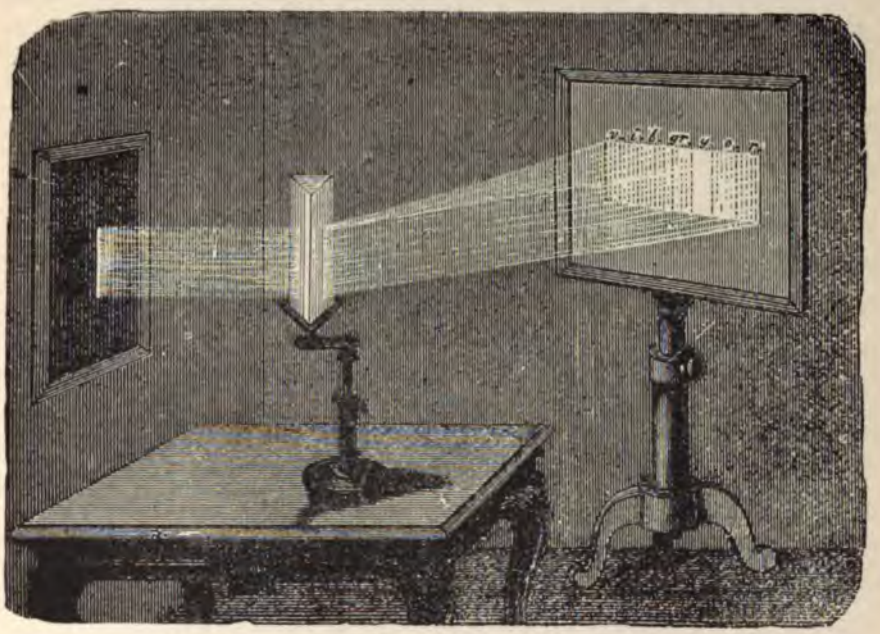
OPTICS.

The Spectroscope. The revelations of the spectroscope are perhaps received by the popular mind with more incredulity than any other achievement of science. Spectral phenomena seen in rainbow tints, the sparkle of jewels, the flash of cut glass, and the changing hues of sunset were familiar long before Newton explained their causes to the Royal Society in 1675. He admitted a ray of sunlight through a small round hole into a darkened chamber and placed in its path a prism whose refracting power spread the rays out like a fan and exhibited its gorgeous color ranging from red, orange, yellow, green, blue, indigo, to violet.

For 127 years no progress was made in that branch of knowledge, but in 1802 Dr. Wollaston admitted the light through a narrow vertical slit and spread the spectrum out in ribbon form, its many lines forming images of the slit. He discovered that the rib-

bon of light was crossed in various places by *dark lines,* but the fact excited no interest at the time.

Fraunhofer, a German optician, in 1814 rediscovered the dark lines. He threw the spectrum on a screen and, examining it with a telescope, was able to count 590 lines, map them, and designate the most important by letters of the alphabet.



WOLLASTON'S EXPERIMENT NO. 1 WITH THE PRISM.

The importance of the spectroscope began to dawn upon the minds of scientists. In 1842 Prof. John W. Draper of New York modified Fraunhofer's spectroscope, cast the lines upon sensitized plates and made photographs of them, but, more important still, passing to the examination of spectra of incandescent bodies, he discovered many fundamental principles underlying that branch of knowledge. Draper's discoveries enabled the astronomer to tell

from the spectrum of a heavenly body whether it was solid or gaseous.

Kirchhoff and Bunsen. Improvements in instruments were constantly made, and in 1859 two German investigators, Kirchhoff and Bunsen, added so much to the knowledge of the spectrum that new metals were discovered by it and the identity of many of the chemical elements of the heavenly bodies were revealed, for "each element gives a peculiar spectrum distinguishable from all others in the number, color, breadth, and grouping of its lines. So distinct are they that when a compound is vaporized all its elements are at once disclosed. If several substances are volatilized together all the spectrum can be identified." *

The delicacy of the operations now performed with the spectroscope almost surpasses belief. It will easily detect 1-18000000 of a grain of sodium, and a blood stain fifty years old containing only 1-1000 part of a grain of blood is revealed in its characteristic lines. In Bessemer steel making the operation lasts about 20 minutes, during which time the atmospheric oxygen burns away the carbon and silicon from the molten cast iron and the heated gases issue in a flame from the mouth of the converter. If the process is stopped ten seconds too early or ten seconds too late, the whole mass is spoiled. The flame changes during the process and the spectroscope reveals the exact moment at which the carbon disappears and the process must be stopped.

The grating spectroscope is now largely used in place of a prism, for it affords a constant standard of reference and "the normal solar spectrum" used as a standard is the spectroscope of the sun mapped with the various dark lines in the position shown by a grating spectroscope. The production of a grating spectroscope is a matter of astonishing mechanical delicacy. Such a spectroscope has a concave

* Youmans' "Chemistry."

spherical surface of speculum metal on which are ruled for an area of 5½ inches by 2 inches, from 14,000 to 20,000 lines to the inch. The delicacy of such lines can be better imagined than understood. It may take months to make a perfect screw for the machine which does the ruling, and often a year is spent in search of a diamond fit for the delicate task of cutting the lines. With such an instrument the solar spectrum can be extended several areas and thousands of Fraunhofer lines rendered visible and photographed.

The Telescope. Historians are not agreed as to who invented the telescope. Certain it is that Hans Lipperhay, of Holland, applied about the year 1608 for a patent for such an instrument, and the Dutch authorities tried to conceal the secret of its construction.

The telescope performed its first important work in the hands of Galileo, who hearing of the Dutch instrument was able by his own mechanical skill and knowledge of optics to construct a better one, and with it discovered the satellites of Jupiter, the crescent phases of Venus, the rings of Saturn, the mountains of the moon, and the spots on the sun's face. "The invention of the telescope created descriptive astronomy. Inquiries into the nature of the heavenly bodies were wholly inspired by it; it disclosed the amazing multitude of the stars and opened endless vistas of research. Thus amid a tumult of applause the telescopic investigation of the heavens began."

The first telescopes were crude affairs with an object glass of a single small lens giving a low power. When, to increase their power, the lenses were made larger, "chromatic aberration" was encountered: *i. e.*, the lenses were not able to bring to an exact focus the different colored light waves, and an image in distorted colors appeared.

The achromatic lens, consisting of a lens of crown glass, convex on each side, in front of a concave lens of flint glass, overcame the most of that trouble. "The crown lens, being convex, converges

the blue rays more than it does the red ones, while the flint glass, being concave, tends in an equal degree to diverge the blue rays away from the axis more than the red ones, so that the combined effect of the two is to bring the rays to a focus." No lens yet made of crown and flint glass has succeeded in bringing *all* the rays to *one* focus. The violet, being the most easily refracted, come to a focus nearest the object glass; the red being the least refrangible, are brought to a focus farthest from the object glass. The violet end of the spectrum is most potent in photography, so lenses which are best for seeing are not best for photography and are corrected for that purpose by a third lens.

Two forms of telescopes are employed: the *refracting* and the *reflecting*. A refracting telescope is one in which a system of lenses receives the rays of light and brings them to a focus. A reflecting telescope is one in which the rays of light are brought to a focus by being reflected from the surface of a concave polished reflector.

The difficulty of manufacturing lenses led Herschel in 1779 to build his reflecting telescope, with which in 1781 he discovered the planet Uranus. Encouraged by his success, he, in 1789, built his great reflecting telescope with which his famous catalogue of stars and star clusters was made. The advantages of the reflecting telescope are that color distortion does not exist because all rays are reflected from a polished surface at the same angle in which they strike it; so in theory there is no limit to its size, but there are great mechanical difficulties in its construction, and if the mirrors are large they are apt to be distorted by their own weight.

Refracting telescopes are now most widely used. The largest reflecting telescope was that of the Earl of Rosse, built in Ireland 1842–1845, having a diameter of six feet, focal length of 54 feet, and costing $100,000.

The Lick telescope, made by Alvin Clark and Sons, was at the

time of its manufacture (1888) the largest of its kind. For the object glass nineteen discs were made, tested, and discarded by Feil and Mantois of Paris, before a perfect one was found. The object glass has a clear aperture of 36 inches and weighs, in its cell, about 600 pounds. The crown-glass lens is .6 inch thick on the edge and 1.91 inch thick in the center. The flint lens is 1.65 inch thick on the edge and .93 inch thick at the center. The lenses are not in contact but are set 6.5 inches apart. The extra lens for photographic work is 33 inches in diameter.

The telescope rests on a solid foundation of masonry, forming the tomb of its donor, James Lick, who at his death left $700,000 in trust for "an instrument that should be superior to and more powerful than any telescope made." He selected as the site Mount Hamilton, 4209 feet above the sea and 26 miles east of San José, California, where the air is so clear that for many months of the year the stars do not twinkle. To make a road from San José to the observatory cost $78,000; the object glass cost $50,000; the photographic corrector, $13,000; the mounting of the telescope, $45,000; the dome, $35,000; and the observatory complete, $600,000.

The Yerkes telescope, given to the University of Chicago by Charles T. Yerkes of that city, has a focal length of 64 feet, with an object glass 40 inches in diameter, made by Alvin Clark and Sons. This was the glass exhibited at the Chicago Exposition in 1893. The Grand Equatorial of Gruenewald has an object glass 42 inches in diameter.

The greatest telescope ever made is that of the Grand Luenette of the Paris Exposition of 1900. This has a tube 197 feet long with an object glass slightly over 48 inches in diameter. The lenses cost $120,000 and the entire cost of the instrument is said to have been more than $400,000. In this glass a decided innovation was introduced. The tube is supported in a horizontal position on

solid pillars. A huge reflecting mirror with regulating machinery, called a siderostat, is placed near the object glass and reflects through the lens the image of the object to be viewed. The mirror alone weighs nearly five tons and is 6½ feet in diameter, with its fittings weighing 33,000 pounds. The whole floats in a bath of mercury.

The Microscope. Awe-inspiring and magnificent as are the wonders of the heavens when revealed by the telescope, the microscope makes us acquainted with infinitesimal life no less wonderful. The microscope, as a single lens, appears to have antedated the telescope. We know the magnifying glass was known to the Assyrians and Egyptians, for the excavations at Nineveh revealed a carefully ground lens of rock crystal. In Europe it was known and used by Zacharias Jansens and his son as early as 1590, and the single lens in the hands of Leeuwenhoeck and others made discoveries of no small importance.

The compound microscope was invented by Farncelli in 1624. Like the users of the telescope, the first investigators with the compound microscope were troubled by chromatic aberration, but the achromatic objective discovered by Euler in 1776 was applied in 1829 by Lister, and an instrument made possible that now combines the contributions of many inventors and is a triumph of the optician's art.

It is impossible to estimate the benefit man has derived from the microscope. Biology, botany, histology, bacteriology, embryology, geology, and chemistry, all are heavily indebted to it. It figures in nearly every department of the useful arts and has revolutionized our understanding of the laws of life and diseases.

The surgeon's debt to the microscope can hardly be overestimated. It is by the studies in fermentation of Liebig and Pasteur, supplemented by Lord Lister's work, that surgery has been deprived of a horror second only to that banished by anæsthetics. Dr.

William Keen says of sights witnessed in his early surgical days: "The parched lips of the poor sufferer, tossing uneasily during sleepless nights, wounds reeking with pus, and patients dying by scores from blood poisoning, from erysipelas, from tetanus, from gangrene, were only too familiar sights in the preantiseptic days. Before Lister's day (1876) these were the dread attendants at almost every operation. To open the head, the abdomen, or the chest thirty years ago was almost equivalent to signing the death warrant of a patient." To-day, in obscure diseases of the brain or the abdomen, if the surgeon is uncertain as to the danger within, he deliberately opens either cavity to find out the exact state of affairs. The revelations of the microscope that made possible antiseptic surgery are estimated to have reduced the mortality of surgical operations from 33⅓ per cent. to less than 5 per cent.

The Microscope Created the Science of Bacteriology. With it Davaine, of France, in 1863 discovered characteristic microscopic bodies in the disease of anthrax. These he named from their shape, bacteria, or little rods, and gave the name to the science.

In 1881 Ogston of Aberdeen discovered the bacteria of pus; in 1882 Koch of Berlin, the bacillus of tuberculosis; in 1883 Febleisen discovered that of erysipelas; and in 1887 Nicolaier and Rosenbaum discovered the cause of lockjaw. With the microscope the physician is able to discover in the morbid constituents of the urine, many unerring evidences of diseases, which only a few years ago were a sealed book to him. Examination of the blood puts him in possession of other evidence no less important.

As a detector of crime it has aided in sending many a criminal to his just punishment. A drop of blood or a single hair is by its aid identified and made to furnish incontrovertible evidence. Its searching powers render futile the finest work of the cleverest counterfeiter. It has taught us how to deal with the blight of grapes and saved

thousands of dollars to the vineyards of France, Germany, and America. It is indispensable to the chemist, the botanist, the steel-maker and the detective, and its range is so wide and its uses so numerous that it would require a volume to catalogue its discoveries.

MECHANICAL PROGRESS IN SURGERY.

By Willard Smith, M.D.

Painless Surgery. October 16, 1846, an experiment was made in the Massachusetts General Hospital at Boston. The result of that experiment, as recorded on a monument, reads thus: —

"William T. G. Morton, inventor and revealer of anæsthetic inhalation, by whom pain in surgery was annulled; before whom, in all time, surgery was agony; since whom, science has control of pain."

The inscription is every word true, but it tells only a part of the great story of what made the improvement in the mechanical part of surgery possible. Naturally, a patient looking forward to an operation as a season of torture almost beyond human endurance would be in the worst possible condition to bear the pain, and this would affect the results unfavorably. The unfortunate effects were not confined strictly to the sufferings of the patient. Few surgeons were hard-hearted enough to be entirely oblivious to the suffering caused by an operation. With his attention distracted by screams of agony, and the field of operation constantly in motion on account of the writhings of the patient, it is not to be wondered at that the surgery of that time was crude and rough as compared with that done to-day. The wonder is that anything was done at all. In addition to the heartrending sufferings, the old-time surgeon had to contend with the unceasing flow of blood. This obscured his field of operation and made the utmost speed an absolute necessity, for life flowed out with blood.

It is now possible by the injection of cocaine into the spinal canal to produce anæsthesia of the entire body below the point of puncture. In this way all the body below the diaphragm can be deprived of sensibility without depriving the patient of consciousness. By this method a man might watch the amputation of his foot, if he chose, but feel no pain.

Bloodless Surgery. A great deal of modern surgery is possible because of the ability of the surgeon to rapidly and surely check the loss of blood. This is usually done by means of the hemostatic forcep, which is simply a little pair of pincers, with roughened jaws, fitted with a catch so that it will remain firmly closed. When, in the course of an operation, a blood vessel is cut, the end of it is seized with a forcep and the pressure stops the flow of blood at once, while, at the same time, the delicate lining of the vessel is lacerated and a little clot is formed which plugs the opening. Hot water, pressure, applied in a dozen different ways, and many other expedients are resorted to for this purpose. Many operations are performed without the loss of a drop of blood, as, for instance, the amputation of a leg or thigh. In such a case the leg is bound tightly from the toes to a point well above the seat of operation with an elastic rubber bandage, thus pressing all the blood out of the leg and forcing it into the blood vessels of the body, where it is needed. Next, a constricting bandage is tightly wound around the leg above the point of operation to hold the blood out, and the first bandage is removed. This leaves the leg entirely bloodless and any operation on it can be better performed.

Many operations which are possible to-day, because the surgeon can take an hour or more for them, were never thought of formerly. Operations were once matters of minutes and seconds, for life hung by the smallest thread. The old-time surgeon had to encounter fully as great difficulties after the operation as during it. The healing of a

wound without suppuration was unknown, and healing by first intention or without the formation of scar tissue was an impossibility on account of the invariable infection of the wound. Secondary hemorrhage, from the literal rotting off of blood vessels that had been tied with necessarily infected ligatures, hospital gangrene, erysipelas, and a hundred other "surgical horrors" were matters of everyday occurrence. They were considered unavoidable until Sir Joseph Lister in 1876 showed the profession that operations were possible without the subsequent formation of pus. As soon as the era of experimental investigation began, surgery emerged from the chaos of ignorance and empiricism and became an exact science. It is now stripped of nearly all that once made it horrible. It is more favorable to the patient, being painless, and thereby giving the surgeon time and opportunity to do better work. It enables him to do with the certainty of mechanical precision that which was formerly utterly impossible. It is needless to say that the results are better and that much less tissue is sacrificed than under the old régime. The field of operation is perfectly stationary, thus permitting great delicacy of manipulation; and, more important than all this, by the exercise of proper precautions the aseptic healing of the wound can be made a matter of almost absolute certainty. All these things make it imperative, because possible, that the modern surgeon do better and more difficult work than was done by his predecessors. The people have a right to demand it of him.

Bacteria are thought to belong to the vegetable kingdom, rather than to the animal, but they are so near to the dividing line that the distinction is of very little practical importance. They are minute organisms, from .000012 to .00006 of an inch in diameter and varying from a spherical form to long rods.

They take an infinite variety of shapes and each kind has some distinctive peculiarity in the manner in which or the conditions

under which it multiplies and grows. It is by these peculiarities that the different kinds can be identified. Thousands of these little fellows have been classified, but we have only begun to get acquainted with their habits. The most common forms are cocci and bacilli. Cocci are spherical and bacilli are rod-shaped. Sometimes bacilli are twisted like a corkscrew and are then called spirilli.

There are several terms which are commonly used in speaking of bacteria and their growth or destruction. A culture is an artificial crop of bacteria, grown for some experimental purpose. A colony is one of the centers of growth of bacteria in a culture. Each kind of bacterium has a peculiarity of colony growth. What is a good culture for one kind may be a very poor one for another. An antiseptic is an agent, generally chemical, which prevents or retards the growth and multiplication of bacteria; a germicide is one which directly destroys the bacteria; a disinfectant is one which accomplishes both purposes.

Operating on the Brain. To convey some idea of the nature of a modern operation let us suppose the case of a patient who has a brain tumor located in the "arm area," or that portion of the brain which controls the action of the arm. After the case has been carefully studied the patient is brought to the hospital and prepared for operation. The preparation consists of two parts; first, the general preparation for the anæsthetic, and, second, the local preparation of the head for the operation. We can dismiss the first by saying that it consists of a systematic course of feeding and purging, extending over a period of two or three days. The local preparation begins the day before the operation with a complete shaving of the head, which is then thoroughly scrubbed with green soap, water, and a scrubbing brush; next, with alcohol, and then with a solution of corrosive sublimate in water in the strength of about 1 : 2000. The head is then securely bandaged in a compress wet with the corrosive

sublimate solution and left thus till the next day. In the morning, before the patient is sent to the operating room, the same process is repeated in every detail. In the meantime, very busy preparation has been going on in the operating room. Every nook and corner of the room has been thoroughly washed with strong antiseptic solutions, and made as free from germs as is within human power. A human life is at stake, and any carelessness or negligence would be, in the light of modern knowledge, little short of murder. Every particle of the dressings, bandages, sponges, and other articles necessary to the operation has been rendered germ free. To do this has required labor lasting during three days. The surgeon, assistants, and nurses then go through a very thorough and rigid course of preparation, so that there will be no possibility of any one of them carrying infection to the patient. A chain is no stronger than its weakest link.

All being in readiness, and the instruments sterilized, the patient is anæsthetized and placed on the table. The dressings are removed and the head given a final scrubbing, even more vigorously than before. Then the exact position for the operation is determined and marked on the bone. A horseshoe-shaped flap, sometimes larger than the palm of the hand, is cut, leaving the narrow part or pedicle in such a position as to allow an undisturbed artery to carry the necessary blood to it for its nutrition. The cut which marks this out is made through to the bone, and then at each of the "corners" a hole about half an inch in diameter is made through the skull with a trephine, which is an instrument especially designed for the purpose. The flap of scalp is left attached to the bone, for it is through this that the bone must receive its nourishment when it is cut off from its usual supply. From the hole on one side of the neck of the flap to its fellow on the opposite side, inside the skull and hugging it very closely indeed, a fine wire saw is passed, and the skull is sawed almost

through from the inside. Then with a mallet and sharp chisels, the bone is cut through all around the line originally marked out. When it is all free three levers are put under its edge and by prying it up the neck or narrow part is completely broken loose and the whole piece is turned back like a trapdoor, using the unsevered skin as a hinge. This exposes the dura mater, or tough membrane which covers the brain. This membrane is picked up with delicate forceps, snipped open, and the brain is brought into view. After seeing the tumor, if the surgeon decides that it can be safely removed he carefully cuts it out. All bleeding is then stopped by mechanical means, and the dura is carefully stitched over the space, a small opening being left through which passed the material best suited to insure drainage. Lastly, the trapdoor is closed and the skin accurately stitched together. The previously sterilized dressings are now applied, and the patient put to bed, to be carefully watched and assiduously nursed till recovery takes place. The after treatment, so far as surgical measures are concerned, consists of the renewal of the dressings when necessary and the removal of the drainage device at the proper time.

Such, in general, are the steps in a typical surgical operation. There are hundreds of details which we have not attempted to describe, as well as thousands of variations to suit the individual case or operation.

It used to be the rule when a bullet entered the brain not to attempt to find it or get it out because it was thought that an attempt to remove it would probably give rise to more danger than the presence of the bullet itself. Now these bullets are located either by the X-rays or by systematic probing and are removed almost as readily as from any other part of the body.

Skin-Grafting. Burns often leave horrible scars which, by their subsequent contraction, cause great deformities. Among the worst

of these are the burns of the neck and chest, which cause such contraction of the superficial tissues as to draw and hold the mouth open in a ghastly and hideous manner. Burns of the hands occur which shrivel them and draw them out of shape so that they become ugly and repulsive and are rendered practically useless. Modern mechanical surgery has been able to relieve most of these unfortunates. The process consists of cutting out the unhealthy scar tissue and transplanting a new skin upon the granulating surface that is obtained. It is not necessary that the skin be of exactly the same kind as that which formerly covered the part, for none of the skin which is actually transplanted becomes a part of the permanent skin. What nature requires in this case is a pattern. The granulating surface is covered with a kind of cells which is very different from those which make up the skin or mucous membrane. The proper variety of cells might, in time, grow in from the sides of the open wound, but before this necessary time could elapse a new scar would form which would be just as bad as the original one, or perhaps worse. So the surgeon plants on the raw surface some of the kind of cells which makes up the skin. These may be taken from man or from almost any animal. Some operators take little snips of skin, the size of a pin head, from the whole thickness of the skin, while others prefer to shave off the outer layers of the skin from an area large enough to cover the entire raw surface. When the skin from the bellies of frogs is used, as it is frequently, the whole area is covered. The surface on which these grafts are placed is made thoroughly aseptic and every detail of the operation is conducted so as to preclude the possibility of the part becoming infected. If any pus appears the hope of a successful outcome may as well be abandoned. *

* Dr. William Keen, in speaking of modern surgery, says: "The surgeon who does not get primary union without a drop of pus, with no fever, and with little suffering asks himself, What was the fault in my technic?"

The grafts, whatever be their shape, size, or thickness, are simply placed on the raw surface, carefully protected, and kept moist. In the course of a few days, the original grafts disappear entirely and at each point where they were placed will be seen a small pearly point. Nature has found the pattern for which she was seeking, and the tissues have begun to form the sort of cells from which skin is made. In this way, the surface is covered with a large number of little islands of new skin and the whole task is divided up into many small tasks, for the skin grows in all directions from each of these islands at the same time. The process of recovery then becomes a race between the formation of healthy skin and the formation of scar tissue. If the skin wins the case will be cured; if the scar tissue wins, a little gain will be made, and the operation can be repeated with a reasonable hope for ultimate success.

Straightening Crooked Bones. Bow legs and knock knees are unsightly and inconvenient deformities which, thanks to the progress of mechanical surgery, can now be successfully treated. The operation is varied for each case, but, in general, the procedure is to break the bones by some method, setting and holding them in the desired position until they have grown to it. Club foot is cured by lengthening the shortened tendons and holding the foot in the proper position until the tendons have healed. In some long-standing cases the bones are deformed to such an extent that a wedge-shaped piece of bone has to be taken out of the convex side in order to allow the foot to be forced into its proper position. The treatment of these conditions is a matter of mechanical ingenuity and the making of the plaster of paris casts which are used to hold the parts in their proper position, and which must be comfortable to the patient and without dangerous pressure, gives the surgeon ample chance to show his mechanical skill. It should be considered a punishable neglect for parents or guardians to allow a "hunchback"

to go without surgical treatment, as by proper treatment many of these unfortunates can be saved from lifelong deformity. The cause of this condition is tuberculous disease of the bodies of the vertebræ. It has been proved beyond question by many examples that if these patients are placed in a position of absolute rest and all weight taken from the spinal column, the disease process will tend to abate and although perfectly healthy bone and normal movement of the joints cannot be secured the progress of the disease will be stayed and much of the deformity obviated. The matter assumes additional importance when we consider that tuberculous processes seldom arise in the lungs but usually begin in some other part of the body and are transplanted to the lungs. This treatment for tuberculosis of the vertebræ is a distinctly mechanical one and has only become markedly successful since a special class of physicians has given close attention to the mechanics of surgery. The little patient, for such patients are usually children, can be kept in a position of absolute rest by strapping it down to a bed, but this deprives it of the fresh air and the exercise of the parts of the body which are not diseased, both of which are valuable aids to a cure. It also tends to produce bedsores and all the wasting and diminution of vital force which enforced inactivity causes. All that is necessary for the success of this treatment is that the spine be kept in a state of rest, and a large variety of apparatus has been devised which enables the condition of rest to be maintained without enforcing the position of rest. This opens up an almost unlimited field for mechanical invention, as each case must be studied to learn exactly what form and arrangement of apparatus will keep the spine absolutely quiet and, at the same time, not restrict the movements of the other parts of the body.

Surgery and Consumption. A few cases of pulmonary consumption have been treated by the operative method. It is too

early to predicate results, but much hope is entertained. As already stated, tuberculosis of the spine can be arrested by simply placing the part at rest. The same rule applies to all other parts of the body, but it is very difficult to secure rest in the lungs, which are filling and emptying about 17 times every minute, day and night, making them the most unfavorable part of the body in which to arrest a tuberculous process. The method suggested and used by Murphy of Chicago, and others, is to inject nitrogen gas into the pleural cavity. There is no mystery about the action of this method for it is all in accordance with mechanical common sense. The nitrogen is placed between the chest and wall and the lung proper and as the lung is, in some respects, like a distended elastic bag, as soon as nitrogen, or any other gas, is forced into the place this bag occupies the bag collapses. When the lung collapses it ceases action. It is known, from actual experiment, that enough breathing can be done with one lung to support life. So the other lung has to do double duty for a time while the collapsed lung gets the rest it needs. The nitrogen is slowly absorbed, and in the course of several weeks it will all disappear and the lung will gradually and easily resume its regular duties. But, in the meantime, it has been placed in the most favorable condition for the healing forces of nature to put a stop to the tuberculosis and in some cases seems to succeed.

Surgery's Battle with Cancer. One of the most dreaded diseases is cancer. If not treated, it is certain death; treated in any but the most thorough and correct manner and at the proper time, the outlook is fully as gloomy; properly treated in time, the prospects for recovery are, in a large proportion of cases, very good indeed. This statement could not have been made a few years ago. Modern surgery has partially conquered this disease. It must be remembered that during the time when cancer is curable it is entirely painless. After the pain begins, there is very small chance of re-

covery, as the disease has then usually progressed so far that it is beyond the power of the surgeon to do more than partially relieve the pain and remove the stench. It can be treated successfully only by cutting out all the diseased tissue and also all that which will, in the judgment of the surgeon, sooner or later become the seat of an extension of the pernicious cell growth. One of the most frequent locations of cancer is the female breast. Before there is any pain felt, and when there is only a slight swelling which the patient is often deluded into thinking harmless, "because it does not hurt," there are signs and symptoms which will enable the surgeon to detect the true nature of the trouble. As soon as the disease can be recognized is the time and the only possible time to effect a cure. To do this the entire mammary gland is removed and all the muscles underlying it, until the bony wall of the chest is laid bare and clean. Then the lymphatic glands around and under the collar bone are taken out and the arm pit is laid open and all the glands carefully and thoroughly dissected out. This latter part of the operation is very delicate work and has to be done slowly and carefully. The operation, when properly performed, frequently requires two or three hours of the best work of the most skillful surgeons, aided by their trained assistants; for nothing short of absolute and complete removal will be of any avail. This leaves an enormous wound but it can usually be almost, if not entirely, covered by loosening the skin from the surrounding tissues and drawing it over the open wound. If an uncovered space is left it must be covered later by skin grafting. Notwithstanding the severity of this operation, the patient can usually be out of bed in a week and can use the arm to some extent in the course of three weeks. This would not be possible if anything but the most rigid aseptic precautions were used. That is what shortens the time necessary for recovery and what, in fact, makes recovery from such a mutilation at all possible.

Removal of the Stomach. The world was startled, a few years ago, by the report that the entire stomach had been removed and the patient had recovered. This was done and the patient did recover entirely from the operation, but afterwards died from a recurrence of the disease for which the operation had been done,— cancer of the stomach. It is an unfortunate fact that when this disease has progressed to such an extent that a patient will consent to have the stomach removed, the tissues surrounding the stomach have usually become involved, and even then the removal of the entire diseased organ will not cure. The only way to cure it is to take out everything that has gone to the bad, and everything that has been in bad company, for reformation is not possible in this matter. Once an organ has become the seat of the peculiar form of cell growth which constitutes cancer, it cannot be cured. The only hope is to remove it at once and prevent its doing any further damage by inducing the same condition in adjacent organs.

The removal of the stomach has been accomplished with perfect success in a number of cases, but in none of them has it been undertaken as a cure. All that was hoped was that a few more months or years might be added to the life of the patient. The operation in itself is difficult but no more difficult than many others which are performed every day and from which cures have regularly resulted.

Surgery of the Eye. The most delicate branch of surgery is the surgery of the eye, and it is a branch which has made very rapid progress in recent years. Hundreds of different operations, all of the most delicate and precise character, are now performed on the eyes and a great number of persons are given either perfect sight, or some sight, who would otherwise be doomed to hopeless blindness or to such imperfect sight as to render them practically helpless. Cataract is a common eye disease which, if not treated, will cause blindness, but it can now be successfully treated in the majority of

cases. In the normal eye there is a little lens which is transparent and which has the power of so changing its shape as to enable it to focus on the retina rays of light from objects at different distances. Cataract is caused by this lens becoming clouded or opaque. The treatment is to remove the diseased lens. This is a most delicate operation, and one in which a mistake of a hair's breadth will surely and irreparably blind the patient. The lens having been removed, its place is supplied by a convex glass placed before the eye, but not in the eye, as many suppose. Without the help of the glass, the operation would be futile because nothing but a glare of light could be seen. With two or more glasses for use at different distances, a fairly good vision can be obtained. Any gain whatever in the power of seeing, when otherwise blindness would be inevitable, is a gain worth risking a great deal to secure.

Sometimes blindness is caused by a scar on the cornea, that clear, watch-crystal-like window which forms the front of the eyeball. When the scar is so situated as to cover the pupil and still leave a clear space at the side of it, a new pupil can be made by removing a portion of the iris, thus restoring the sight. Squint or cross-eye is a very unsightly affection and one which usually forces the patient to use only one eye. Most of these cases can be cured by operation on the muscles which move the eyeball. By a slight lengthening of certain tendons and a slight shortening of others, the proper balance can be restored and the patient be given a practically perfect pair of eyes again.

Eyes are sometimes so badly injured or diseased as to necessitate their entire removal. When this is done, there is either a hideous gaping cavity as a result, or else a glass eye is inserted. When done in the old way, this glass eye always stared straight ahead, producing fully as disagreeable an effect on the observer as would the open socket. Mr. Mules, an English surgeon, has devised an operation

which does away with this disagreeable feature. Instead of taking out the whole eye, he cuts off the cornea and thoroughly scrapes out all the contents of the eyeball. This leaves the hard and tough shell or sclera, to which are attached the muscles which move the eyeball. After the wound has healed, there is a solid stump left in the socket which can be moved in any direction at will. Over this is fitted a glass eye, which moves with the stump and follows the movement of the other eye. The results of this operation are so good that in some cases it requires a very close inspection to detect that one eye is an artificial one.

Vaccination. May 14th, 1796, Dr. Edward Jenner, an English physician, inoculated James Phipps with cowpox as a preventive of smallpox and thus scored a triumph over one of the most dread diseases to which humanity has ever been subject. Prior to this discovery the frequently recurring ravages of smallpox had been frightful. In Russia it had been fatal to no less than two million persons in a single year; in 1707 six per cent. of the entire population of Ireland died of the disease, and in England it was unusual to see an unscarred face. Now smallpox is one of the rarest of diseases and is seldom fatal under skillful treatment. Notwithstanding the evidence from all sides as to the efficacy of vaccination, there have not been wanting opponents to the procedure. It is impossible for anyone with any acquaintance with the nature of the evidence to see on what grounds such opposition is based.

Hundreds of other examples might be mentioned, but the foregoing are enough to show how closely modern surgery is related to mechanical progress. It is a truly gratifying thought that the possibilities of modern mechanics is not limited to the building and perfecting of mere inanimate temples, but that it is a potent factor in preserving and bettering the "Temple of the Soul."

THE HOUSEKEEPER'S DEBT TO INVENTION.

The inventions of the nineteenth century have been grand and far-reaching; they have girdled the earth and followed the stars in their courses, but what they have done for the women of the world, laboring faithfully in multitudes of quiet homes, outweighs all other consequences.

From the home emanate the qualities which make or mar a nation's life; hence, whatever gives opportunity to the women who make the homes, rises superior to that which gives merely financial results. Science tells us that the physical part of man must be sound or there will be failure in the mental part, and the mental side must be healthy or the moral side will be weak; that the early years, the years spent in the home, make the deepest impression on the future, and these years are in the hands of the mothers and home-makers.

Our grandmothers (dear old ladies) did not have even the chance that the women of to-day have, to take an occasional look at Science and then walk proudly in her steps. They baked, they brewed, they spun, they wove, they churned, they ironed, they knit, they braided, they dyed, and then they died. We fear they did not have time for much else in their lives. The inventions that make many things easy for the women of to-day were then unknown and Science did not speak so loudly as she does now of the necessity of right physical living.

In order to realize what invention has done for the home and the

housekeeper, it will be necessary to take a little trip back into what Mrs. Stowe called the "jog-trot days" — the days of our grandmothers — and see how life ran with them.

Like Solomon's wise woman, our foremother arose with the sun. It was original sin to be lazy. Satan in those days found no "idle hands" with which to do "mischief." It was a matter of time to make the fires in the great fireplaces, for phosphorus matches, which expedite so many things for us, were not in general use until about 1840, and our foremother must get the spark with which to light the fire by the use of flint and steel. For lighting purposes she sometimes used fat pine knots; then came candles which she laboriously made from beef tallow; after candles came pungent smelling whale oil lamps, while many burning fluids and then kerosene oil followed somewhat later. Invention had not then brought to her aid the lighting and heating powers of gas and electricity.

For the breakfast, dinner, and supper of the household she had to depend upon her own resources; no caterer, no canned goods helped her in an emergency. Perhaps she had a smoke house and salting tubs for beef and pork, and prepared her own bacon, ham, beef, and fish; for, in some way, she must be ready as cook to feed her household. She preserved and pickled; she brewed beer and made wine from currants, elderberries, and grapes. She raised medicinal herbs and distilled potent curative essences and ointments. She made butter and cheese with none of the modern conveniences. Having saved her refuse grease, she went to the leach barrel and with wood ashes proceeded to make lye for soap.

The "sitting room" needed a carpet and this patient, all-enduring woman cut and sewed rags, then, from the old hand-loom came an oriental looking web into the warp and woof of which were woven things precious as love, courage, and faithfulness.

The custom of braiding mats was as universal as carpet weaving,

and the house-mother also braided the straw hats which her "men folks" wore during the summer months, while she sometimes earned money for a coveted treasure, which could not be obtained otherwise, by braiding hats for the "store."

"Hannah's at the window binding shoes" was not a myth or poetical fancy but a workaday fact, and by binding shoes many a woman helped increase a scanty income.

When it became too dark for other work, that time might not be wasted, the knitting needles were plied in nearly every home. One old writer enumerates: "They knitte hose, knitte peticotes, knitte gloves, knitte slieves." They knit so much that it became automatic and they could knit with their eyes shut, so that, seeing them, one involuntarily parodied Hood's Song of the Shirt: —

"— till over the stocking she fell asleep
But still knit on in her dreams."

At the beginning of the century knitting was universal; even as late as the Civil War it was still a part of woman's work, and many stockings were knit for soldiers as the homemade article better endured the wear and tear of the march; but the great stockinet, shirt, and woolen factories have relegated this work to the things of the past.

This ancestress of ours, for whom we are sorry and of whom we are proud, was a manufacturer. She took the flax which had been grown for the purpose and wove it into linen to make tablecloths, shirting, sheets, and garments. To prepare this linen it is said that over forty bleaching manipulations were necessary. She took the fleece sheared from the sheep, washed, carded, and spun it, and then wove it into cloth. She gathered sassafras, the bark of red oak, and of the hickory nut, and with alum, logwood, and various other compounds, dyed the cloth whatever color she desired, and from this

cloth she made the garments of her household. To the ceaseless whirring of her wheel she might well have sung with Tennyson's Enid: —

"Our hoard is little but our hearts are great."

The great canning industries whereby immense quantities of fruits, vegetables, meats, and other perishable stuffs are preserved to feed the hungry world were then unimagined, nor had she the smaller helps such as apple parers, fruit corers, and driers; but her household must be fed during the barren months, so with her two hands and a knife she endeavored to save as much as possible of the swiftly decaying apples, pears, peaches, plums, quinces, currants, and grapes by drying and preserving in various ways.

In the household of the past there was a great demand for pies, which must be "shortened," and, as there were no accommodating butchers to stop frequently at her door for orders, into her day's work came the task of trying out lard from such portions of our porcine friend as would yield the desired lubricant.

These are only some of the ways the woman of the past, by unsparing, unceasing labor, accomplished her many and arduous tasks.

Science makes it clear that much of this brave work was disastrous to herself and to those who came after her because the laws of health were constantly violated; but, "with all her imperfections on her head," as the light from the beacon of science streams back over the nineteenth century, it gleams upon nothing more admirable than our valiant foremother. But after a survey of our grandmother's work who would be willing to again take up the white woman's burden?

The home is the most fundamental fact in a man's life aside from his inherited qualities, and even these come from past home influences, and Science, recognizing that the mother, the home-maker, cannot carry burdens that strain every nerve and muscle and at the

same time cultivate an intelligent understanding of the relationship of the body to the mind, has come to her aid with inventions and machinery designed to lighten her drudgery and give her time to widen her outlook. The past may have been against her, but the future is with her, and invention and machinery are her handmaids.

Consider some of the inventions that have a direct bearing on the work of the mother and housekeeper. While many of them add to the luxury of the wealthy, non-producing one tenth, most of them are designed to help the nine tenths, Lincoln's "plain people" who produce the wealth and bear the burdens of their country.

Chief among modern health promoters we must count sanitary plumbing and sewerage systems; also the cementing of cellars; and it seems impossible to speak with too much enthusiasm of the great advance made in heating and lighting. From the open fireplaces with their immense logs — from the later air-tight stoves, to the coal, gas, steam, and electric heating and lighting of the present is a long step, and few homes are now so poor that these great inventions do not radiate some comfort upon them, while inventors are promising still greater things for the future. This means better health in the homes as well as less work and greater cleanliness.

The great modern cooking range with every possible adaptation for its purpose, and providing for the use of either or both coal and gas; the oil, gasoline, and gas stoves, saving heat in summer and time in winter, are all comparatively recent and are among the housekeeper's greatest blessings.

Perhaps in this connection, the Aladdin Oven, patented by the eminent statistician of Boston, Prof. Edward Atkinson, should be mentioned. Mr. Atkinson claims that "very much good material is wasted in cooking" that can be saved by the use of his oven, that flavors lost in ordinary cooking are retained, and that it is impossible for food to be overdone or underdone. The heat is furnished by an ordinary "Rochester" lamp.

If we consider the water service, we find hot and cold water pipes in nearly every house with bath room, a laundry with set tubs, and a never-failing supply of hot water for the kitchen, laundry, and bath room. The labor incident to the weekly wash is further lightened by washing and wringing machines, while the self-heating flatiron is an additional comfort and convenience.

Around the housekeeper and cook crowd many inventions, for the cooking question is a serious one, and the conservation of the natural powers is largely in the hands of the housekeeper.

The great Dr. Samuel Johnson said, "Dinner is the most important event of the day," and it certainly is on that day when all the dear ones come trooping home to partake of the Thanksgiving feast. Then, if ever, the wise housekeeper realizes her need and calls to her service all the aids that invention can give her. By telephone she orders turkey and chickens, and by the aid of cold storage and fast freights they have come from a distant state in fine preservation. To save time and work she uses canned vegetables and has June peas in November. She has only to use a can-opener and her soup is nearly ready. With seven hundred patented churns on the market, this housekeeper can if she wishes make her own butter, but butter from the creamery is just as good and saves time; with a patented whip-churn she prepares the cream for the table in a moment; with a Dover egg-beater she prepares eggs for the pudding, and, as she flavors it, is glad she need not make her own extracts. She bakes her pies in an oven with a glass door and by the aid of an oven thermometer. She makes ice cream in a patent freezer, prepares potato with a patent potato-masher, brings cheese from a distant factory and pickles from the neighboring store, and makes ready the nuts with a patent nut cracker. Dinner having been served, the washing of the dishes is quickly accomplished by the aid of a patented dish-washer, and as this busy home-maker puts away the remnants

of the food in her commodious refrigerator, she thinks what a blessing is ice and is almost thankful that the "good old days" are in the limbo of the past.

But the labor saving inventions used in preparing this dinner are by no means all that lighten the housekeeper's burden. There is the sausage grinder, the egg boiler, the waffle iron, the steam boiler, the apple parer, the milk cooler, the centrifugal cream skimmer. There is oleomargarine, lard, and the beef extracts, and in connection with the great help the housekeeper has received in the preservation of food by ice, it may be said that at the present writing it promises to become cheaper and more general, as an electric ice machine has been invented which the inventor promises to adapt to private use, so that in the near future the housekeeper can prepare ice cheaply and in such quantity as may be wanted.

Science is helping to give the housekeeper time to see more of the beauty of the world in which we live and to realize something of the forces that make and govern it. The cook is surely among those forces. A recent writer says, "Anarchists are the result of a university education upon an empty stomach," so it behooves to keep the world well fed.

The preparing of three meals a day, three hundred and sixty-five days in the year, makes the food question and the inventions and discoveries that touch upon it a very intimate one to the home-maker, but there are other sides to the home and invention has reached out a hand and lightened them all. Some of the helps may appear small to others than the housekeeper but she well knows the relief they have afforded her. Years ago women were dressmakers and tailors for their families, but Howe's sewing machine came in 1846, and, after a time, it immensely lightened the housekeeper's work. A woman no longer makes the clothing worn by her husband and sons, and even her own clothing is largely shop-made. With carpet

factories on the right and on the left, women have lost weaving out of their lives, but some of them, like Penelope, still cling to embroidery. She cares for her carpets with the carpet sweeper and the carpet renovator, and, if she prefers a bare floor with a rug here and there, she will find that a machine for making rugs has been invented, and in 1894 a machine for sewing carpets. If for any reason this housekeeper wishes to use dyes, she need not compound them herself in wearisome ways, but she will find that brilliant dyes have been prepared for her by the chemist. In place of the feather bed, she has the hair mattress, and perhaps with it the folding bed which may be a bed when so needed and something else when something else is preferable. Does the mistress wish "to set" a hen? There are incubators and she would better make use of one than do as did the Reverend Doctor of whom Mrs. Stowe tells, who had a fight with an old tom turkey to make him perform that office, coming off second best.

The list of helps is long and every housekeeper will be able to lengthen it by the addition of something that has been of exceptional benefit to herself.

The numerous inventions in many lines to lighten household drudgery give the housekeeper a chance to improve the quality of the work which she does for those she loves best; they give her time for other things and enable her to bring what we are accustomed to call the lower functions of life into the place designed for them — that of co-operating with all other forces to give life on earth its best conditions, conditions that will lessen drudgery, want, and grinding misery; that will help in building up harmony, peace, and happiness in the home; that will lengthen the span of human life; whatever, in fact, tends to make life in all its phases better worth living.

UTILIZATION OF WASTE PRODUCTS.

This is the day and date of the by-product, and the chemist is abroad in the land, going back over the ground, making use of what

was formerly wasted, until there is hardly a single staple of human industry taken from the earth that he cannot duplicate with materials gathered from some despised refuse..

The scales of fish such as "menhaden" and "alewives" are not in themselves attractive, but they are worth $1.25 a pound, and under the magic influences of a French chemist appear as pearls to adorn the neck of beauty. The Lucifer match, first made in 1833, uses phosphorus largely obtained from old bones. In Paris a large pit is prepared into which the carcasses of animals are thrown and innumerable rats soon clean the bones, which are then used in making phosphorus. The hoofs are used in the manufacture of glue, and from time to time the surplus of rats are killed, their skins made into "kid" gloves, and their tendons and bones boiled to furnish the gelatin wrappers for bonbons.

In 1871 a refrigerator was mounted on car wheels, filled with dressed beef, and started for an Eastern market, where it arrived in good condition. Its success revolutionized an industry, for it was cheaper to slaughter the cattle and ship the edible portions wherever needed than to ship the cattle alive. Further, it insured a better quality of meat.

What Becomes of the Steer. Organized concentration means economy, and large packing houses rendered possible the utilization of many waste products. A steer just off the plains, weighing 1500 pounds, furnishes about 825 pounds of dressed beef. The horns are converted into combs, buttons, and hairpins. The hard shin bone is made into knife and tooth brush handles, buttons, and bone ornaments. The hoof is made into hairpins and buttons. The hide goes to the tanner. The hair is made into insulating felt or sold to the plasterer. The feet, knuckles, hide, clippings, sinews, and small bones are made into glue, gelatin, isinglass, neat's-foot oil. The tail goes to the soup and the tuft of hair is used in mattresses.

STOCK YARDS.

The tallow and grease are made into toilet and laundry soaps, washing powder, and all grades of glycerin. The blood is made into buttons or used to refine sugar; and all waste of a nitrogenous character from the different parts of the carcass is taken to the fertilizer works and converted into fertilizers, stock and poultry foods, phosphorous acid, phosphorus, boneblack, black pigment, sulphate of ammonia, bone oil, and many other products. It once cost the packers of Chicago $30,000 a year to remove and destroy the undigested food found in the stomachs of animals slaughtered there, and now it is made into paper.

The pig's bristles are made into brushes and his stomach and pancreas go to the laboratory and are made into pepsins, pancreatins, and other medicines. The wool is taken off the sheep pelts, cleaned, and sold to woolen goods and felt manufacturers. The skin is tanned and made into leather. The thyroids and some other glands are made into medicines.

Such is the system employed by the late Philip D. Armour. Everything was utilized under the supervision of expert chemists working in well equipped laboratories; the cost of food was reduced, and all portions of the animal not used for food, clothes, glue, soap, or in the arts and sciences were returned to the farm as fertilizers, to aid in growing more grain to feed more live stock. Small wonder that so great and so well organized a business made money for him.

Cotton Seed. With every pound of cotton fiber there is produced two pounds of cotton seed, and this product, formerly despised, now threatens to rival petroleum in the multiplicity of its uses. The seed is first ginned to remove the "crapo cotton," a short, fine fiber highly prized in making gun cotton; it next passes between rollers which crack and remove the hulls from the meats. One half the hulls furnishes sufficient fuel to run the mill and the remainder is sold as food for cattle. The ashes from the hulls burned at the mill

furnish lye or caustic acid to refine the oil. The meats are passed through rolls, which reduce them to a pasty mass and are then cooked so that the oil can be more easily extracted. They are then placed in bags within the press and the oil squeezed out, leaving behind oil cake, which is ground and sold as oil meal, even then worth more for cattle food than corn.

As a cattle food, cotton seed meal will produce 41 pounds of lean beef as against 31 pounds for bran, 22 pounds for peas, 12 pounds for corn, and 11 pounds for rye. As a fat producer a given quantity gives 57 pounds for cotton seed, 54 pounds for bran, 50 pounds for peas, 68 pounds for corn, 72 pounds for rye, and 50 pounds for hay.

The by-products of cotton seed have been so thoroughly utilized that one investigator declares they have added $1.25 an acre to the value of cotton lands and detracted $1.65 an acre from the value of corn lands.

The Oil has Many Uses. Shipped to Europe it returns as "best olive oil." Mixed with beef-stearin (another waste product) to harden it, it becomes "pure lard," and government tests have shown that its food value is fully as high as hog lard with less liability to become rancid. As an illuminant it ranks between sperm oil and lard oil. It burns well in the miner's lamp and is largely used for that purpose, but is not good for paints or lubrication. It is largely used in soap making and in advertising one popular brand (Ivory) the fact is stated that it is made from *pure cotton seed oil.* Mixed with 18 per cent. of crude india rubber it makes a good imitation and is used for cheap bicycle tires. The manufactured products from one ton of cotton seed are worth about $20, and the field of usefulness is widening.

Coal tar is a thick black sticky compound obtained in the manufacture of illuminating gas from coal. For many years it was an in-

sufferable nuisance, with its offensive odor, and was surreptitiously dumped into rivers to get it out of the way. It is not strictly accurate to say that the coal tar colors, saccharin, etc., are contained *in* coal tar, but rather that they are made *from* things derived from it. No other article furnishes so many useful products. As an illustration, it may be likened to a long word which the chemist resolves into letters with which he spells many other words, just as the letters "a," "t," and "r," may be arranged to mean "rat," "tar," and "art." Almost any substance on the earth derived from a vegetable product can be duplicated by the chemist with some coal tar derivative. The U. S. Dispensatory credits coal tar with derivatives as follows: 13 solids, 40 liquids, 16 illuminating gases, 3 heating gases, and ten or a dozen other things classed as impurities. From it are made saccharin, a substance 300 times sweeter than sugar; picric acid, from which the famous lyddite explosive is made; and artificial flavoring extracts counterfeiting so cleverly almost any flavor that exists in nature that only an expert taste can detect the difference. It furnishes perfumes that cannot be distinguished from heliotrope, queen of the meadows, cinnamon, bitter almonds, wintergreen, thymol, etc. Some coloring materials that were so transitory as to be thought worthless are now indispensable for tinting photographic plates for colored photography. Among the drugs made from it are phenacetin, antipyrin, antifebrin, quinine, exalgine, hyponol, sulphonal, and so many others that the modern physician would find it hard to name all his medicines that are "coal tar derivatives."

The coal tar colors are now more important than the natural ones and constitute four distinct classes: the aniline, the phenol, the azocoloring matter, and the anthracene series, in all comprising more than 2000 different shades. In 1881 Prof. V. Bayer produced indigo by making it from its chemical constituents, but his experiment was too costly. Other German chemists took the hint and continued

the researches. To-day one company in Baden annually manufactures as much indigo from coal tar as could be produced from 250,000 acres of land in India. Indigo is the chief industry of the province of Bengal, and hundreds of thousands of families depend upon it for existence. If the land can be made to produce food, all the better for the natives.

Kerosene is but one of the numerous products of petroleum, and the rest form such a list one might think it a cousin of coal tar. Paraffin, vaseline, cosmoline, rhigolene (an anæsthetic), cymogene (used in ice machines), gasoline, lubricating oil, fuel, benzine, asphalt, etc., chewing gum, aniline dyes, and several medicines are but a part of the list, and the end is not yet.

Corn, though not a waste product, now has other uses than to make whisky and pork. Glucose, made from it, is converted into a very good substitute for rubber for some uses. From the pith of the corn stalks cellulose for the water line belts of battle ships is made, and as paper can be made from anything that has a fiber, the husks and stalks of the corn can be used for that purpose.

Improved methods have made it possible to work over the waste heaps or "tailings" from gold mines worked years ago. When a roof was put on the mint in Philadelphia the leaden covering of the old roof was melted and yielded $827 worth of gold and silver deposited there by invisible fumes arising from the furnace. A wooden floor used for years in the establishment of one of the largest watch-case making firms of New York city was burned and yielded $67,000 worth of gold.

Seaweed or kelp, once considered one of nature's waste products, is a source of wealth. Each ton will produce 8 pounds of iodine, several gallons of volatile oil, three or four gallons of naphtha, from 150 to 300 pounds of ammonia sulphate, and considerable quantities of potassium chloride. It also furnishes products used for food, drink, and medicine, and can be made into vegetable isinglass.

Blast furnaces are now charged with extravagance. Carefully conducted tests in England have shown that blast furnace gases formerly allowed to escape will in the cylinder of a gas engine furnish a horse-power-hour from every 100 to 120 cubic feet of gas, and that the average blast furnace of Great Britain wastes 14,000 horse power a week. In other words, if the power were economically employed it would be worth more than the iron produced. Germany has become aroused and is putting in gas engines, converting the waste into electricity, and using the latter for every possible practicable purpose.

Slag from blast furnaces is made into bricks, paving-stone, tile, commercial fertilizer, wool; and the end is not yet, for it contains from 55 per cent. to 75 per cent. of pure oxygen. So valuable has the fertilizer proved that several large steel plants have been located in the midst of the purely agricultural portions of Germany.

Coke furnaces are also forced to plead guilty to the charge of wasteful extravagance. It is estimated that each ton of coke made by the beehive method gives off 4000 cubic feet of gas that is wasted. In addition there are 20 pounds of ammonia sulphate and from 40 to 100 hundred pounds of coal tar. Germany has a system of coking that utilizes these by-products to such an extent that their value more than pays for coking the coal, while it is estimated that $20,000 a day that might be saved goes up in smoke in the coke regions of western Pennsylvania.

HOW TO MAKE AND PATENT AN INVENTION.

Senator Platt of Connecticut has said: "Of the seven wonders of the ancient world only one, the lighthouse of Pharos, was for human good. The seven wonders of the modern world, the cotton gin, adaptation of steam to methods of transportation, appliances of electricity in business pursuits, harvesters, the modern printing press,

the Bigelow loom, and the sewing machine, are all for the benefit of mankind. The cotton gin and the sewing machine have given the human body a new skin. The steam engine is the breath and muscles, and the telegraph the nervous system of the body politic. In the production of the electric light man has come nearer to creation than anywhere else. The epoch of news came in with the Hoe press, a new dimension for cities with the vertical railway,— the elevator,— and the era of cheap food with McCormick's reaper. The typewriter is the sewing machine of thought and introduces an era of legible manuscript."

The man with an original idea has a commodity which the world needs and he has a right to demand and receive payment for it. Many a man lives who has in his mind a vague idea of some device he thinks patentable and from which he believes he could reap a fortune. The majority of these dreams never assume tangible form. Some die in the attempt to give them practical shape; others pass through the preliminary stages successfully and are rejected by the Patent Office. The sifting process of the Patent Office disposes of many. However, rather more than half the applications pass the final inspection and a limited number of these actually make fortunes for their owners. The difficulties in the way of carrying inventions to their completeness suppress many visionaries with their impracticable schemes but they also bury under some worthy inventions. The latter are too valuable to be lost and it would be better to inspect a hundred useless ideas than to lose a single worthy one. Invention is an erratic faculty. The instruments it uses are common to all, but it follows no prescribed rules of practice with respect to time, place, or circumstance. Some of the best products of inventive genius have appeared in the most unexpected places and probably always will.

Infringement Suits. On May 19, 1899, the heirs of William A.

Brickill were awarded $894,633 for an infringement suit against the city of New York, which had been in litigation twenty-nine years. Brickill was a foreman in the New York fire department and patented a feed water heater for steam fire engines in 1868, which was adopted by the city. On leaving the department he asked the city to pay for his device. The authorities contended that he did the work while in the employ of the city. The decision is important, for the courts have decided that employers are not entitled to the inventions of employees unless there is a special contract to that effect.

In 1900 another suit of about thirty years standing was decided against the city and $818,074.72 awarded the plaintiff for a "relief-valve" that would enable a fire-engine pump to run at full speed no matter how many hose pipes were connected to lead off the water. The city had adopted the valve but regarded the royalties asked as excessive. Thirty years of litigation ensued, resulting in a verdict against the city, for it was shown that the saving in hose amounted to $183,394.32; the saving in labor, $606,344; and the saving in repairs, $28,336.

Profitable Inventions. Some patents are readily salable. The German government paid the Strowger Automatic Telephone Exchange of Chicago $500,000 for the patents and right to manufacture and use their automatic switch.

One of the striking peculiarities of inventions is that the profit to the inventor is so often out of all proportion to the seeming value of his idea. Eli Whitney lost money perfecting the cotton gin, but a patent for a particular kind of fastening for kid gloves has brought its owner several hundred thousand dollars. A collar clasp brings the owner of its patent a royalty of $20,000 a year, while a peculiar form of sleeve button which struck the popular fancy brought the owner of that patent $50,000 in five years. The roller skate made $1,000,000 for its owners, copper tips for children's shoes and gimlet

pointed screws paid well. The man who discovered that a candle if tapered at the end would fit securely into its holder, patented the idea and afterwards founded the largest candle factory in the world. Improvements in umbrellas netted Samuel Fox at least half a million pounds. Fortunes are to be made in small and apparently insignificant common things. A man may have an invention which seems to him of little practical value, yet it may be the very thing the world wants badly enough to give a fortune in exchange for it.

"**A patent may be obtained** by any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvement thereof, not known or used by others in this country, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, and not in public use or on sale in the United States for more than two years prior to his application, unless the same is proved to have been abandoned.

"A patent may also be obtained by any person who, by his own industry, genius, efforts, and expense, has invented and produced any new and original design for a manufacture, bust, statue, alto-relievo, or bas-relief; any new and original design for the printing of woolen, silk, cotton, or other fabrics; any new and original impression, ornament, pattern, print, or picture to be printed, painted, cast, or otherwise placed on or worked into any article of manufacture; or any new, useful, and original shape or configuration of any article of manufacture, the same not having been known or used by others before his invention or production thereof, nor patented nor described in any printed publication.

"**The applicant**, if the inventor, must make oath or affirmation that he does verily believe himself to be the original and first inventor or discoverer of the art, machine, manufacture, composition, or improvement for which he solicits a patent, that he does not know

and does not believe that the same was ever before known or used, and shall state of what country he is a citizen and where he resides."*

Inventions usually arise to fill some want. An inventor sees some work done, or is engaged in doing it, and a plan occurs to him by which it could be done better, quicker, or cheaper; or, using or seeing used some piece of machinery, possibilities of improvements in it present themselves to his mind. To avoid hopeless confusion it has been found necessary for every patent office to adopt certain stringent rules. It is with the hope of furnishing to some would-be inventor not familiar with the subject some knowledge of the course of procedure required that this article is presented. If the inventor will carefully ascertain what has been done by others in the line on which he is working, much valuable time and effort can often be saved, for there may be later and better methods than those he has seen employed or later and better machinery may be actually on the market. The quickest and best way to obtain this information is to consult an honest and capable (the species is not extinct) patent attorney, a man whose professional training fits him to quickly secure for the inventor the accurate information he needs. The attorney will usually furnish this for a small fee, for if the idea of his client is patentable he knows that he stands a good chance of having his services retained when the idea is ripe for patenting.

The experienced solicitor can avoid pitfalls and take advantage of opportunities which would be unseen by the inexperienced inventor; can point out complications, infringements, suggest mechanical equivalents — a different manner of arriving at the same result — and aid in steering clear of many difficulties. After finding that the proposed invention is probably patentable the next step is to perfect it, for the first conception is usually rather crude and incomplete in detail, and changes are frequently necessary to avoid infringement

*Rules of Practice in United States Patent Office.

on another patent. If the device is of such a nature that absolute secrecy is impossible in the necessary tests, the safety of the invention may be protected by filing a "caveat."

A caveat is in no sense a patent for a limited term, but entitles the inventor for one year to receive from the Patent Office notice of any application for patent likely to interfere with his right. "The caveat may be renewed, on request in writing, by the payment of a second caveat fee of ten dollars, and it will continue in force for one year from the date of the payment of such second fee. Subsequent renewals may be made with like effect." A caveat gives the inventor more time in which to perfect his device before making final application for patent. "Any citizen of the United States, or alien who has resided in the United States one year next preceding the filing of his caveat, and has made oath of his intention to become a citizen, and who, having made a new invention or discovery, desires further time to mature the same, may, upon the payment of a government fee of ten dollars, file in the Patent Office what is known as a caveat. The caveat must clearly set forth the object of the supposed invention and its distinguishing characteristics. Caveat papers are filed in the confidential archives of the Patent Office."* The advantage in this provision is that it aids in establishing the question of priority in case the ensuing patent should ever be contested. It also lengthens the profitable life of the patent and enables the inventor to get it in working condition before placing it on the market.

The next thing to do is to make accurate drawings and a working model (if the invention is one which can be demonstrated by a model), and make sure that the invention will do all that is claimed for it. Never apply for a patent until this has been done and the practicability of the invention has been established.

It is better to intrust the application to a patent solicitor, but if

* "Patents." Hawson and Hawson.

the inventor wishes to carry it through unaided he can get very complete and explicit directions published under the title of "Rules of Practice in the United States Patent Office," and which can be obtained from that office, in Washington, D. C.

The application for a patent requires a written specification, drawings (no model, unless asked for by the examiner), an oath of invention, and the payment of the first government fee of fifteen dollars.

"The following order of arrangement should be observed in framing the specifications: —

"1. Preamble stating the name and residence of the applicant, the title of the invention, and, if the invention has been patented in any country, the country or countries in which it has been so patented and the date and number of each patent.

"2. General statement of the object and nature of the invention.

"3. Brief description of the several views of the drawings (if the invention admits of such illustration).

"4. Detailed description.

"5. Claim or claims.

"6. Signature of the inventor.

"7. Signatures of two witnesses.

"The specifications must be signed by the inventor or by his executor or administrator, and the signature must be attested by two witnesses."*

"The specifications and claims form the most important part of an application for a patent, and the part for which, most particularly, inventors find the services of a competent solicitor not only desirable, but necessary. If the specification incorrectly or insufficiently describes the invention, so that persons skilled in the art

* Rules of Practice in United States Patent Office.

cannot, from the description, practically make and use the invention, or if it fails to particularly point out what part of the matter described the patentee claims as his own invention, then the patentee has failed to comply with the conditions and requirements of the law, and his patent is bad. As to the claim, it is the patentee's own definition of his rights, by which he must stand or fall. The law will not give him more than he has chosen to claim, nor help him out if he has not claimed all that he might have done. So far as ascertaining and defining the extent of the patentee's right is concerned, it is his claim which constitutes the patent." *

The applicant must not expect that his claim will receive immediate attention, for it will be considered in its regular order. If, when it has been passed upon by the primary examiner, the matter claimed appears to be new, the applicant or the solicitor who represents him will be notified that the application is "allowed," and that a patent will be issued upon the payment of the further government fee of twenty dollars, provided it be paid within six months. From the payment of this last fee till the patent is actually issued three weeks usually elapses. The total expense is $35.00 for the government fees, plus the fee charged by the solicitor, if one be employed.

If the primary examiner considers that substantially the same thing as that claimed by the applicant has been previously patented or described in a printed publication, he reports adversely to the commissioner, who sends a letter of rejection to the applicant or solicitor, stating the exact cause for the rejection. An appeal may then be taken to the examiners-in-chief and from their decision to the Commissioner of Patents and from his decision to the Superior Court of the District of Columbia. If the applicant wishes to push his claim he will do well to intrust his case to a competent lawyer.

When a United States patent has been granted, its duration is

* "Patents." Hawson and Hawson.

"seventeen years from the date of issue, unless the inventor has, before the issue of the United States patent, patented his invention or caused or allowed it to be patented in a foreign country. In that case the United States patent will expire with the foreign patent; or, if there be more than one, with that having the shortest term."

Civilization rose from savagery and depends for its very existence upon the encouragement and development of the inventive faculties. He is a benefactor of mankind who devises some method whereby any branch of human labor may be made less irksome or more productive. In return for the security in the possession of life, liberty, and property which society gives to him the inventor owes a debt which he should repay by putting his invention in shape to be of practical use. On the other hand, society recognizes its debt to the inventor and has provided a method whereby he may receive payment for his invention if it is useful to society. This system has two good effects: the invention is secured for the use of the people and it is secured in its best possible form, for the inventor's financial success depending upon the merits of the article and its general use, he will spare no pains to make it as good as he can. The United States Patent System does not pay the inventor for his invention, but, on the other hand, the army of inventors pay all the expenses of the Patent System. This system has for its sole object encouragement of invention by affording protection to the inventor, his heirs, or assigns, in the unmolested use and sale of the invention for a term of years in which he may amass a fortune if the invention be really valuable. "A United States patent is a contract. The parties to it are the inventor on the one hand and the people of the United States on the other. The inventor, by a public record, informs the people concerning a useful discovery which he has made, which must be original with him and new in the United States. In return the people, by their letters patent, secure to him the exclu-

sive right to make, to use, and to sell his invention for a limited number of years. At the end of that period the contract terminates and the discovery belongs to all the people forever. Whether the thing contrived is to underlie a great industry, or whether it is merely an improved pin, the inventor, to be entitled to his patent, must disclose it fully and without restriction or reservation; so that, when the patent term shall be finished, the public may be able to make and use the thing as well as he himself can make and use it."

First Patent. The earliest record of any patent is the one granted by Edward III. of England to "two friars and two aldermen" who claimed to have discovered the philosopher's stone. Laws for the encouragement of inventors gradually developed a patent system in Great Britain and this system has become a parent to most others. In the American colonies, each colony for a time had the power to grant patents. The first one recorded seems to be that of Samuel Winslow, who in 1641 was granted a ten years' patent by the General Court of Massachusetts on a process of salt making. Since then over 600,000 patents have been issued in the United States. The first United States patent law was made April 10, 1791, but the Patent Office was not established until 1836. The cost of maintaining the United States Patent Office is about $1,250,000 annually. As there are about 43,000 applications annually for patents of which 26,000 are granted, the fees of the applicants more than pay the expenses of the office.

Statistics gathered by Edward W. Byrn for the *Scientific American* show that at the close of the nineteenth century nine countries had issued 1,819,906 patents, of which the United States granted 37 per cent.; France, 18 per cent.; Great Britain, 16 per cent.; Belgium, 9 per cent.; Germany, 7 per cent.; Austria-Hungary, 5 per cent.; Canada, 4 per cent.; Italy-Sardinia, 3 per cent.; and Spain, 1 per cent.

Thomas A. Edison, to whom more patents have been issued than to any other inventor living or dead, says that if he had his life to live over again, he would protect his inventions by secret processes rather than by patents and take his chances on the results. The reason he assigns is that the delays incident to an infringement suit allow the guilty party to carry on the infringement with profit for a length of time which, in many cases, has almost if not quite equaled the term of the patent, and has thus virtually defeated the very object for which the patent was issued. The expense incident to these protracted suits may be so great as to more than exceed the damages recovered. Though the "secret process" method might be available for much of Edison's work, implements simple in design and intended for general use could not be so protected. However, just as necessity stimulates invention, the urgent need of better patent laws will ultimately bring the required legislation.

"The British method is to grant, as a matter of course, any regular application for a patent, no matter whether the device has been the subject of a former patent or not, and then to leave the patentees to fight out their respective rights afterwards in the courts."

MACHINERY, LABOR, AND WEALTH.

Denis Papin made a steamboat about two hundred years ago, and started down a German river to go to England, but he encountered a prejudice none the less strong because mistaken, for the boatmen, who plainly saw that this innovation meant the loss of part of their livelihood, fell upon him, destroyed his boat and the inventor barely escaped with his life. Such was the first appearance of the power destined to revolutionize the industrial world, and such the reception it encountered. This spirit has been too often exhibited and has not yet wholly disappeared. The experiences of the inventors of cotton machinery have already been detailed. One of the

greatest strikes that England has witnessed appears to have had its inception in the introduction, by Hiram Maxim, of a number of new milling machines into the factories of the famous Vickers, Maxim and Co. The machines were automatic and one man could easily run six or seven. The Trade Union declared that a man must be employed for each machine, and a long and bitter struggle ensued destructive and expensive alike to capital and labor. But as the innovation increased the production and reduced the cost, it won, as such inventions must win in the long run. Progress is an irresistible force crushing relentlessly labor or capital that recklessly attempts to bar its course. In numerous printing offices of America a similar opposition was shown toward typesetting machines, but such opposition has only retarded and not prevented their introduction.

Does Machinery Displace Labor? Without doubt it often temporarily deprives a workman of employment, but it is no less certain that it sets in operation a chain of industrial forces that in the aggregate result in increased production at lower price, and in the increased employment of labor. The man temporarily out of a job is not inclined to be philosophical, and the introduction of new machinery frequently works great hardships, but the world is changing and demands that whatever is for the greatest good shall be brought to pass, even if a few individuals must be offered up to the god of progress. Labor-saving machinery has oftenest displaced labor of the lowest order and has thus emancipated man from much labor which was hard, brutal, and degrading. The age of "main strength and stupidity" has passed and the workman is no longer a machine, but an intelligent being, whose business it is to think and to control machines.

Mention has been made of the cotton gin and it will not be denied that although it was a labor-saving machine it also stimulated the employment of more labor than any other invention but the steam engine.

Prior to 1830 nearly all the inland freight was hauled in wagons drawn by teams. With the advent of the locomotive the labor and capital so employed was forced to seek new fields, but who will contend that the introduction of the locomotive has not benefited labor?

A half century ago saw the introduction of machinery into watch-making. Prior to that time the work had all been laboriously performed by hand, but soon American machine-made watches were competing successfully with the best products of Switzerland. Automatic machinery, intelligent workmen, skillful organization, have enabled two companies, the Waltham and Elgin, to put out millions of watches, pay out millions of dollars to their workmen, and still furnish timepieces so cheaply that the laborer of to-day can carry a more accurate watch than could the rich man of a hundred years ago. The cheapened product has made it possible to employ far more labor than the industry could have supported had it been confined to hand labor. Even in a business requiring so high a degree of skill on the part of the workmen as watch-making, rarely has the introduction of automatic machinery displaced as much labor as it created a demand for, and the workmen of the Elgin Company have for a quarter of a century made better wages at "piece work" than the average market wages for day work, while strikes among them are unheard of and the best of feeling prevails.

Frequently an automatic machine is introduced that performs only a part of several operations engaging a single workman. This certainly means the employment of a workman for each machine, an increased product, and the employment of additional workmen to take care of the product.

Typesetting machines are not such unmitigated evils as compositors feared, for the officers of the Typographical Union now state that in their judgment as many persons are employed in setting type as formerly, and the manufacture and sale of the machine

have given employment to fully as many persons as their introduction displaced; while the stimulus to other branches has been marked, cheapening the product, increasing the production, widening the sale, creating a demand for more type, employing more men to make it, more paper, more stereotypers.

Before the advent of wood fiber an increased demand for paper called forth that picturesque figure, the rag peddler, who, with his cart and jingling tin, was such a familiar sight as he wended his way through the New England and Middle states gathering an otherwise waste product.

Inventions Create Occupations. Inventions not only create an additional demand for labor but frequently create occupations, witness the Bell Telephone Company, using a quarter of a million miles of wire and furnishing employment to 25,000 people. The telegraph, the electric cable, and the locomotive are other good examples. In 1899, the Interstate Commerce Commission reported that there were 928,924 railway employees in the United States alone. When electric street cars were put on between Minneapolis and St. Paul, carrying people every few minutes, it was complained that they had thrown men out of employment on the steam road. The electric road did displace eight men on the steam road, but it furnished work for 65 men on the electric line.

Suppose a new line of railroad is to be built through the Northwest, and men of the usual type now employed by contractors for that kind of work are making "cuts" and "fills" for the roadbed. The introduction of a steam shovel or of a steam ditcher will necessarily deprive some of these men of work, but it will shorten the time of the construction of the road and lighten the cost, and that road when completed will give employment to a large army of switchmen, brakemen, engineers, conductors, telegraphers, foremen, superintendents, and managers,—labor surely as valuable as that

displaced by the steam shovel. Settlers are waiting the completion of the road, traffic is waiting for it, machine shops and rolling mills are busy preparing its locomotives and steel rails, blast furnaces are glowing, the coal and ore for all these operations is mined and transported, and the quicker the roadbed can be completed the sooner can all these forces be set to work. Does Machinery Displace Labor?

Increased Production. Seventy years ago ruling paper with a quill and ruler took 4800 hours to do what a machine now does in 2¾ hours. The quill pen man received $1 a day, the machinist $3.50 a day, yet the labor cost is 85 cents as against $4.

A modern printing press can print 96,000 eight-page papers in an hour, while with the best hand presses it would take a man and a boy working ten hours a day 140 days to do it, and the price would be prohibitive. Many other illustrations could be cited.

At the Atlanta Exposition, not long ago, five mountaineers gave an exhibition of the manufacture of homespun cloth by the use of the hand card, the spinning wheel, and the hand loom. Alongside and in operation, was the most modern machinery for doing the same work and each method employed five persons. Hand labor produced 8 yards of cloth in ten hours while machinery produced 800 yards of better cloth in the same length of time. Comment is unnecessary.

Does Increased Production Benefit Mankind? A farmer, a weaver, and a shoemaker supply each other's wants, and each in turn produces a bushel of wheat, a yard of cloth, and a pair of shoes in a given length of time. Suppose each introduces improved tools that double his productive capacity; then it follows that in the same length of time and without extra effort they can be twice as well fed, twice as well shod, and twice as well clothed. If machinery increases the output per man, there must be an increase in the production,

and as the supply becomes greater the price falls and brings within the reach of the workmen many things that were formerly considered luxuries while it permits him to have still more of the common necessities. The workmen are in the end the consumers of their own products and, as the wealth of the world is increased, the workman gets his share of the increase.

Machinery and Wages. Labor-saving machinery has been used only about 125 years and it is not strange that the early writers on economics, reasoning from insufficient data, should arrive at erroneous conclusions. The relations of machinery to labor and social betterment have been carefully studied and exhaustive researches made by carefully appointed experts in various countries, and much more accurate and extensive knowledge is now available. In the United States the Senate Committee of Finance investigated 21 separate industries represented by about 100 distinct establishments and ranging from 1840 to 1891. Starting with the assumption that the wages of 1860 were fair average wages from which all the others were to be computed, those of 1840 stood 82.5 per cent.; 1860, 100 per cent.; 1866, 155.6 per cent.; 1891, 168.6 per cent. In other words the wages of 1891 were more than double those of 1840. The average annual earnings of persons engaged in manufacture — men, women, and children — was for 1850, $247; 1860, $289; 1870, $302; 1880, $347; 1890, $445.

Experiments conducted by the British Department of Labor and labor bureaus of continental Europe show the same general upward tendency of wages, the countries ranging as follows: United States, Great Britain, France, Belgium, and Germany. It is an interesting coincidence that, judged by patents issued, the countries that have encouraged the improvement of labor-saving machinery rank about the same, viz.: United States, France, Great Britain, Belgium, and Germany.

It appears that wages have, generally speaking, a constant upward tendency. What of the necessities of life? Similar experiments conducted by the Senate Finance Committee show that 223 of the leading articles of consumption fell in price from 100 per cent. in 1860 to 94.4 per cent. in 1891; then the price and purchasing power of labor in 1891 measured by the price and purchasing power of labor in 1860 shows a gain of 68 per cent. The wage earner further shares in the benefit of the invention, for the hours of toil have been shortened from 12 and 13, to 8, 9, and 10 hours per day.

Progress Sacrifices Capital. It is true that labor-saving machines displace some workmen, although they create a demand for many more, but such losses are not confined to labor alone. "Industry in its march takes no care of the positions it overturns nor of the distinctions it modifies. It always accomplishes its work, which is to make better goods at a lower price, to supply more wants and always those of a better order, and to secure for man greater comforts and conveniences, not with regard for any class, but having in view the whole human race. True to its instinct it has no sentiment unless it is for its own interest."*

Marked changes in industry often create a greater demand for labor, yet are expensive to capital. The Bethlehem Steel Company constructed, at a cost of about a million dollars, the largest steam hammer in the world. It was hardly well in operation before Sir Joseph Whitworth's method of "fluid compression" and hydraulic press forging rendered the hammer useless for the purpose for which it was constructed. Improvements in transportation have frequently caused locomotives to be thrown in the scrap heap for no other reason than that larger and more powerful ones might be put in their places. The Kinzua viaduct was recently rebuilt at great expense, not to remedy any fault in construction, but because more powerful loco-

* Carroll D. Wright, "Practical Sociology."

motives, hauling longer trains, imperatively demanded a stronger bridge. When the Suez canal was built it ruined many British ship owners, who had millions of dollars invested in the sailing trade with Australia, for the canal shortened the route enough to make it practicable for steam vessels. Every one is familiar with the machinery discarded, not because it is worn out, but because it is outclassed by improved machinery.

Machinery Increases Wealth. The steam engine, labor-saving machinery, and the production of cheap steel have wondrously increased the wealth of the world. Steel is the foundation upon which the whole structure of civilization and industrial life is reared and any reduction in its cost or improvement in its quality tends to increase its use and consequent benefit to mankind. There is a close connection between the wealth of the country and the amount of iron and steel it consumes. In the United States the wealth per capita in 1820 was $200, the consumption of iron and steel, 40 pounds; wealth in 1850, $350, iron and steel, 85 pounds; wealth in 1870, $700, iron and steel, 175 pounds; wealth in 1890, $1050, iron and steel, 275 pounds; wealth in 1900, $1350, iron and steel, 375 pounds. A like relation is shown between the wealth of the world and the steam power used. Mulhall, the eminent statistician, stated in 1896 that the United States turned out 25 per cent. of the manufactured products of the world with 12 per cent. of the operatives, "showing the great economy of labor due to the unusual use of improved machinery."

Prior to the introduction of the Bessemer process, all nails were made of iron and largely by women, and it was the proud boast of Sir Henry Bessemer that he had lifted from slavery 60,000 woman nail makers of England. To-day steel nails are made by machinery, and so cheaply that if a carpenter stops to pick up a nail accidentally dropped, he wastes more time than the nail is worth.

Machinery and Savings Banks. If one may judge the condition of the people in moderate circumstances by the reports of the savings banks, the states of Rhode Island, Massachusetts, Connecticut, and New York, where the factory system plays an important part, compared with the states of Illinois, Indiana, Wisconsin, and Minnesota, where agriculture is the chief industry, furnish important testimony. Of the men, women, and children of Massachusetts 53 per cent. are depositors in savings banks as against 0.14 per cent. of those of Wisconsin, and New York has nearly 100 times as many depositors as Indiana. The following table shows the number of depositors in each of the states named, the average amount of the deposit, and the ratio of the depositors to the total population:—

	Number of Depositors.	Average Deposit.	Ratio of Depositors.
Massachusetts	1,491,143	$358.01	53 per cent.
Connecticut	393,137	442.94	43 per cent.
New York	2,036,016	452.89	28 per cent.
Rhode Island	142,096	517.18	33 per cent.
Indiana	21,091	267.93	0.7 per cent.
Illinois	208,992	309.95	4 per cent.
Wisconsin	2,945	192.93	0.14 per cent.
Minnesota	51,418	234.67	3 per cent.

Many of the Eastern savings banks are at a disadvantage because the rate of interest in the East is lower than in the West. Contrasted with such an exhibit is the historical fact that prior to the introduction of the factory system in England, pauperism was so great that one fourth of the expenses of the government went to their support, and that since that time it has been constantly on the decline.

Division of Wealth. Mulhall estimates that the last decade has made an addition of $25,000,000,000 to the wealth of the United States, a saving unheard of in the history of the human race, and Mr. Powers, statistician of the twelfth census, says that this is a

greater saving than all the people of this continent were able to make from the time it was discovered by Columbus to the breaking out of the Civil War, and that the saving represents more houses, buildings, machinery, tools, implements, clothes, and means of transportation than the whole human race was able to add to its savings from the time of Adam to the Declaration of American Independence. It is not true that the rich are growing richer and the poor poorer. The wage earner is better housed, better fed, better clothed, better educated than ever before and enjoys advantages of civilization unknown to employers even a generation ago, and has comforts that kings of a century ago were unable to command. In 1829 nine of the heaviest taxpayers of Boston owned over 8 per cent. of the wealth of the city. In 1899 the nine heaviest taxpayers of Boston owned but 4 per cent. of the city's wealth. In 1845 the 333 richest men of Boston owned a greater portion of its wealth than do 1200 of its richest citizens to-day. The wealth of the world has enormously increased; the rich are growing richer and the poor are growing better off.

The globe could not support its population if deprived of the benefits of the steam engine and the labor-saving machinery attendant in its train. Rae, the eminent Arctic explorer, states that every Indian within the territory of the Hudson Bay Company requires 20 square miles of land from which to make a living by hunting and fishing. The Royal Geological Society a decade ago estimated the world's population at 1,487,600,000, and if this is even approximately correct there are now living in the world 620 times as many people as could be supported on a civilization no lower than that of the North American Indian, and Manhattan Island, which now supports a population of 1,850,093, would, if deprived of the benefits of modern civilization, only afford a living for two.

Armour Institute, Chicago.

APPENDIX.

MAN'S WORK AND TRAINING.

THE choice of an occupation is of greater moment than formerly. Time was when the son followed pretty closely in the footsteps of his father and all the male members of a family were members of one profession. It was easier to choose an occupation then, for the choice was limited. To-day, professions are extending their invitations that were unheard of a generation ago. It seems unfortunate that one of the most important decisions in life must be made by a young man when he is the least fitted to make that decision, and when it is only too likely to be influenced by mere desire or ephemeral fancy rather than aptitude, fitness, and qualification, both mental and physical, which should be the determining factors in the selection of a profession. The occupation cannot dignify the man so much as the man may dignify the occupation. It is a season of unrest and change, and new lines of employment are constantly being opened, offering fascinating inducements to young men, and affecting materially the earnings of those in the older professions. One hundred years ago it was an unusual thing, and almost something to be deplored, for a Harvard graduate to enter business instead of taking up one of the learned professions, but all this has changed. Two hundred years ago the large landowner was making the most money; one hundred years ago it was the shipowner; to-day it is the manufacturer, and the young man in selecting an occupation should take into consideration the tendency of the times, his fitness, and decide accordingly.

The great use of machinery has sprung up wholly within a century and a quarter. It seems plainly evident that the present cen-

tury is to witness the greatest development of industrial forces that the world has ever seen. Statistics show a constant and steady gain of the skilled over unskilled workers, and one is not heeding the signs of the times who neglects the warning and relies on strength alone, for the proportion of labor that calls only for muscular exertion is becoming smaller and smaller.

This fact is becoming generally recognized, and the increasing number of manual training schools, trade schools, technical schools, technical departments attached to great universities, and institutes of technology show the general trend of interest. There are a few trade and technical schools on the American continent that compare favorably with those of France, Belgium, Switzerland, Germany, Austria, Scandinavia, but in general the European schools are superior.

Manual training schools are such as, in addition to regular educational courses, give instruction in tool work. In trade schools the great consideration is the mastery of a trade with some attention to general education. The technical school bears the same relation to the trade school that the high school does to the grammar school, for it teaches not only the handicraft but the principles upon which it is founded. Institutes of technology give a technical education ranking with the universities and confer degrees on their graduates as civil engineer, electrical engineer, mining engineer.

The industrial schools of Europe are fitting young men for many trades with a thoroughness which seems particularly characteristic of the German, and easy means of communication, quick and cheap transportation, are breaking down national barriers and making it constantly easier to move to the places where there is the greatest demand. Australia, Canada, and the United States are looked upon in continental Europe as especially promising fields and the Mecca for the young man after he has finished his industrial education at

home. The moral is obvious — the American must be equally well prepared.

Medicine. It seems reasonable to believe that as the people become better educated and better acquainted with the laws of life, as sanitary engineering improves and as medical science continues to add to its long and honorable series of victories, that there will be less and less demand for physicians. The specialist will do better than the general practitioner and in selecting the specialty it will be well to remember the strain of modern life upon the eye, the ear, and the nervous system. One of the most eminent physicians of New York city says the regular physician who in five years establishes a practice that supports him does well.

Law. If the young lawyer is to become eminent, certain specialties in law, as criminal law or some branch of corporation law, seem to offer the most brilliant prospects.

Music, painting, and sculpture seem to offer better prospects than ever before on this continent, for, with increasing education, wealth, and leisure among the people, the artist will receive larger patronage.

The instruction in the schools of art and design range from designs for wall paper and carpets to building cathedrals. The following are a few well known art schools: The Art Students' League, 215 W. 57th street, New York city; tuition $4 to $12 a month; a few scholarships and prizes are awarded. The New York School of Art, 57 W. 57th street, New York city; tuition $5 to $15 a month; several scholarships and prizes are awarded. Cooper Union, Astor place, New York city, has free night schools for men where instruction in mechanical drawing, architectural drawing, decorating, designing, modeling, etc., are given. The Pennsylvania Academy of Fine Arts, Philadelphia, has two terms of 17 weeks each; tuition $10 to $30 per term; several valuable prizes and scholarships are awarded. The Museum of Fine Arts, Boston; tuition $115

for a year of 33 weeks; pupils are limited to 200. The Art Institution of Chicago has perhaps the largest enrollment of pupils; tuition $50 to $75 a year. Among others, equally meritorious, are the Art Academy of Cincinnati, the St. Louis School of Fine Arts, of St. Louis; the Minneapolis Academy of Fine Arts, Minneapolis; Columbia University School of Architecture, New York city. Nearly all of the larger colleges give some instruction in fine arts.

The Polytechnic institutes are all of comparatively recent growth. The first one in the United States was the Rensselaer Polytechnic Institute of Troy, N. Y., founded by Stephen Van Rensselaer in 1824.

Gradually the old system of education, once ample, was shown to be inadequate to meet the requirements of the changed industrial conditions and interests, and separate scientific departments and distinct organizations for technical schools were made. Of these the Sheffield Scientific School of Yale was founded in 1847; the Lawrence Scientific School of Harvard, 1848; the Chandler Scientific School of Dartmouth, 1852; the Massachusetts Institute of Technology, 1865; Cornell, 1868; the Stevens Institute, Hoboken, N. J., 1871; the Rose Polytechnic School, Terre Haute, Ind., 1883; the Case School of Applied Science, Cleveland, O., 1891; Department of Applied Science, McGill University, Montreal, 1878.

The trade school is a product of the nineteenth century. Before the advent of the steam engine, the master workman took apprentices into his own shop and taught them the craft, and he was simply, as the name implied, the master workman. But with the introduction of machinery he became active manager of an industrial establishment, and the old relations were no longer possible, hence the trade schools arose to supply the deficiency. Of these, the Pennsylvania School of Industrial Art and the School of Weaving at Crefeld, Germany, are representatives of this type, which offer special courses

in silk weaving, linen weaving, watch-making, mason work, machine work, brewing, etc. The courses last from three to five years and beside the trade training given, additional instruction is given in mechanical drawing, free-hand drawing, mathematics, bookkeeping, science, etc. The object of these schools is to supply a limited number of graduates fitted to become superior workmen and foremen rather than to train the great body of artisans. The first practical trade school of the western hemisphere was founded in New York so lately as 1881 and the work was at first confined wholly to evening classes. Numerous schools of like character have sprung up, among which is the Pratt Institute of Brooklyn, and none rank higher.

A strong evidence of the value of technical training is seen in the sacrifices men of experience as machinists and draughtsmen are willing to make in order to secure it. Although there has been a rapid increase in this branch of instruction during the past fifteen years, it has hardly kept pace with the increasing demand.

Many of the young men who would make best use of the advantages offered by the technical schools are not wealthy and some of them are limited in general education. All such may be interested in reliable information regarding the entrance requirements of the technical schools, and the cost of a thorough technical education.

Professor Thurston of the scientific department of Cornell University, which may be considered as standard, writes as follows: —

"To enter upon a course of study in a college school of engineering, a good preparation in mathematics is demanded, including as the first requirement, the highest of the high school branches. To enter upon the full course as a candidate for a degree also involves good preparation in other branches of high school study and especially in the modern languages; for the literature of engineering is very largely to be found in the French and German languages. All this means for the average man, the consecration of much valuable

time, much hard work and considerable money to the task of simply preparing for college; but many young men do it, earning their living and paying their way to the highest and best of technical schools and through them.

"Cornell University offers six hundred 'state scholarships,' involving no payment of tuition fees, to those who succeed in a public competition held in all the election districts of the state of New York at stated periods.

"Although the student in a course of college work in mechanical engineering of whatever kind spends hundreds of dollars each year for a number of years to secure his diploma in engineering, much may be accomplished by a man of pluck and ambition, with a spirit of self-sacrifice, on a comparatively small sum. In the larger cities, fortunately for this class of men, are now to be found institutions which facilitate his work in self-instruction and self-education enormously, and the Cooper Institute in New York, the pioneer in this grand work, is a good example. Others are the Pratt Institute, Brooklyn; the Auchinschloss schools, New York; the Drexel Institute, Philadelphia; the Lewis and the Armour Institutes, Chicago, and others, including the best correspondence schools, in which excellent courses of instruction are given.

"In some individual and exceptional cases it is possible to find a way of earning something while in college. One man boasted that he left college considerably richer than when he entered, and another by securing and sub-letting a contract in a remote town, for an electric lighting plant, made a surplus of some thousands of dollars; but these are not cases to be taken as giving much encouragement to the average student. He must usually make a business of study and study only."

F. W. Tyler, Secretary of the Massachusetts Institute of Technology, states as follows: —

"Any applicant needs to be well prepared in algebra and plane and solid geometry as a minimum, whether for a regular or a special course in engineering. Our scholarship funds are in general restricted to regular students who have completed a year or more of good work and are known to be in need.

"Many of our scholarship applicants get on for $5 per week or less for room and board, although such economy involves some degree of hardship."

G. H. Marx of Leland Stanford Jr. University, says: —

"A person who has had a good, common school education, including plane geometry and elementary algebra, but who cannot fulfill the requirements for entrance as a regular student, can enter the university as a special student, provided he is at least twenty-one years of age, and has had practical experience of a nature satisfactory to the authorities.

"There are no scholarships which give a student financial assistance, but a great many students support themselves throughout their course. A man with a trade can earn enough in the shops of San Francisco during the summer to carry him well through the year. A number of our men have done this. The expenses of a student exclusive of clothing and railroad fares need not exceed $225 per year."

From the University of Illinois, L. P. Breckenridge writes:—

"The charges for tuition here are nominal and the cost of living, including all expenses of the student both in the university and out, may be easily as low as $225 to $250 a year.

"I have under consideration the advisability of establishing what we might call a two years course in Mechanic Arts at the University of Illinois, permitting the students to enter it with only the avowed purpose of becoming mechanics rather than engineers. There seems to be very little provision in American educational systems for

educating mechanics. I was very much impressed by our lack of this facility from what I saw in some of the German and English schools."

From H. W. Spangler of the University of Pennsylvania:—

"The actual requirements for admission cover mathematics, including algebra, geometry and elements of trigonometry, elementary physics, English, French, German, and history. The university has a few scholarships available for students residing outside of Philadelphia who are doing the full work of the course.

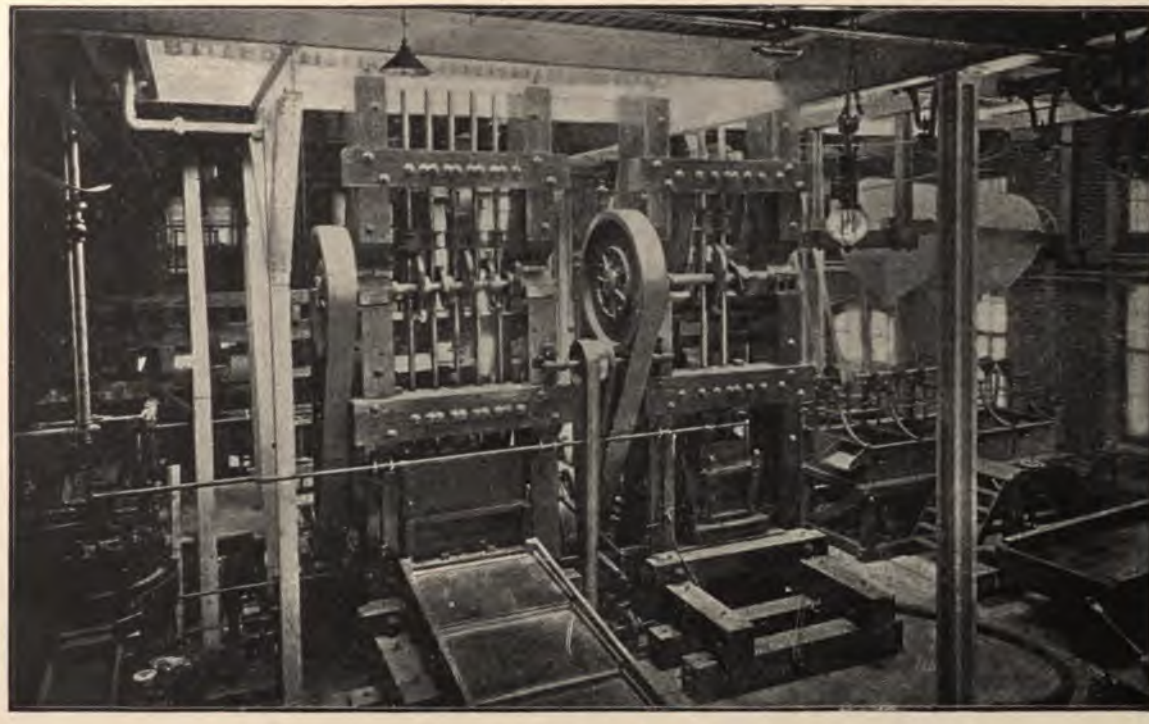
"The cost of a year's work at the university would be made up of $200 tuition; $25 caution money to cover breakage, with any balance returned; room in the dormitory from $45 to $105 for the college year; board at the university restaurant at $3.50 per week; and books and supplies, which will average $25 per year, the first year's expenses being a little greater than the average because of the necessity of purchasing drawing tools."

Palmer C. Ricketts, president Rensselaer Polytechnic Institute, writes as follows:—

"We require for entrance at the Rensselaer Polytechnic Institute the usual elementary English branches, arithmetic, plane and solid geometry, and algebra through quadratic equations. The expenses vary from five hundred dollars a year upward. This includes tuition. We have no scholarships here but are able to give some students quarters free of rent. Efficiency in shop work or drawing would not help offset any deficiency in entrance requirements."

McGill University, Montreal, requires English, mathematics, and French or German, or Greek or Latin, and also an examination in physiography, botany, chemistry, or physics.

Instruction is given in architecture, civil engineering, surveying, electric engineering, mechanical engineering, mining engineering, metallurgy, and chemistry.



MINING ROOM, MCGILL UNIVERSITY, MONTREAL.

There are several prizes ranging from $10 to $100 each and four scholarships, one worth 150 pounds sterling.

The tuition fee is about $156 and board and lodging costs from $15 to $25 per month.

A revolution has taken place in college education. Great universities like Yale, Harvard, Columbia, and Pennsylvania accept studies in the professional schools as meeting the requirements of the last year in college. Yale and Harvard no longer require a knowledge of Greek as essential to admission. A young man can be admitted to full standing in the academic department of the college who has no knowledge of Greek and but little of Latin, and once admitted he is left free to select from a long list of studies, ranging from architecture and music on the one hand to military and manual training on the other, and he can obtain his degree from studies that are purely practical and technical.

MODERN OCCUPATIONS FOR WOMEN.

FIFTY years ago there was one woman wage earner to every ten men. The present ratio is one to four. There are now about three million women and girls in the United States alone who earn their own livelihood. This is one of the striking changes incident to the great increase of business which has marked the age of invention. Not only has invention enabled deft fingers and quick minds to displace mere muscle but it has also opened many new avenues of employment to men and the work dropped by them as they have reached out for something better has been picked up by women.

The primeval man and woman gained a bare subsistence by hunting, fishing, and tilling the ground in a simple fashion, while they had at the same time to contend with wild beasts and hostile tribes of hardly less savage men. As the woman sought places of comparative safety for her children, the easier half of the work, as tilling the soil and preparing the simple meals, naturally fell to her. The humblest working woman of to-day performs feats of skill far beyond the capacity of primeval man, but it still remains, as it should, that the most complex and arduous tasks fall to men.

So long as she could, woman continued to do her half of the world's work in the home, but the development of machinery took the work out of the home into the factory and the workers had to

follow the work. Thus "woman's work" has gradually widened, until to-day women are in business and the professions as well as the industries; they are there with widening knowledge and increasing ability; it is probable they are there to stay. The purpose of this article is to aid, if may be, those who wish to become self-supporting, or to earn more than their present equipment affords, by a partial survey of the occupations now practicable for women. The aim will be to give briefly an approximate idea of the necessary aptitude and preparation, the expense of preparation, and the probable remuneration.

Medicine, of the learned professions, seems to be the one for which women are best fitted and the "woman doctor" may be found in all large towns. There is now no lack of medical schools where women can study in peace, and the catalogue of any of them will give the requirements. The course is from two to four years, according to the statute requirements of different localities, and an annual expenditure of $400 should be allowed for the tuition, board, and incidental expenses of each college year.

The financial success of the woman physician depends upon her personality and tact as well as upon her knowledge of her profession. A comfortable living is assured her when competent, if she can wait a few months to build up a practice. There are comparatively few women physicians who attain a yearly income of over $2500, and doubtless the average income would fall somewhat below the $1000 mark. It should be remembered that this is a most laborious and trying profession to those who have no natural love for it.

The Woman's Medical College, Philadelphia, the Cleveland Homeopathic Medical College, Cleveland, Ohio, the Toronto School of Medicine, Toronto, Ontario, are some of the medical colleges open to women.

The Law. The expense of a course in law is about the same as that of medicine.

The feminine mind seems to have little aptitude for this profession, which keeps one so continually in touch with the seamy side of life, and there are few women lawyers in offices of their own. There is an opening for them, however, as assistants in the offices of large law firms, where they receive salaries from $18 per week upward, according to experience and ability. A course in stenography and typewriting should be included in the preparation for such a position.

Cornell University, Ithaca, N. Y., Boston University, Boston, Mass., Osgoode Hall, Toronto, and other law schools, now give young women equal opportunities with men in preparing for this profession.

The Ministry. There is occasionally a woman who seems as truly called to preach as was ever John the Baptist, and such usually make their way and find their place. The woman who wishes to prepare regularly for the ministry will now find an opening in most theological schools of the various denominations outside the Episcopal and Roman Catholic. These and other churches offer "vocations" to women in which they can make themselves useful as sisters of charity, deaconesses, nurses, and in missionary work. The following institutions have departments for the training of women for different branches of Christian work:—

The Bible Normal College, Springfield, Massachusetts.

The Lay College, Revere, Massachusetts.

The Moody Bible Training School, Chicago, Illinois.

Dentistry is being rapidly taken up by women as a profession and they seem to be generally successful. Before a woman decides to undertake this work she should be quite sure that she has sound nerves, physical endurance, a natural aptitude for fine mechanical

work, and that she is not in the least "squeamish." It is not agreeable work at best, but it is useful and fairly remunerative. As assistant dentist a woman may earn from $15 to $25 a week. In business for herself her physical strength would hardly permit her to earn more than $1500 to $2000 a year unless she attracts so large a patronage as to employ assistants and make a profit from their work. It is said that if the teeth of the people of the United States alone were properly cared for, it would keep 50,000 dentists constantly occupied.

The course in a dental college is three years, and the expense about the same as that for a course in medicine.

The Pennsylvania College of Dental Surgery, Philadelphia, Penn., the Tufts College Dental School, Boston, Mass., the Toronto Dental College, Toronto, Ontario, and many of the dental schools connected with universities admit women.

Nursing is a woman's occupation by natural right, and the work of the trained nurse has come to be esteemed as hardly less important than that of the physician.

Training schools for nurses are to be found in connection with most public hospitals. The usual course is three years. The common requirements are that the probationer be over 21 and under 35 years of age, that she have sound health, good character, a common school education, and evince some fitness for the calling. While in training pupils have a small monthly compensation for their services as well as board, lodging, and washing, with care if ill.

Graduate nurses command from $15 to $25 a week for their services, but it should be remembered that the work is too arduous to admit of constant employment and that the nurse may earn no more in the course of a year than a woman with smaller weekly wages who seldom loses a day's pay.

Infant's Nurse. The position of a trained nurse for infants ranks

with that of the trained nurse for the sick, while the work is more agreeable, less wearing, and the employment less fluctuating. That infant is to be counted happy who is consigned to the care of a refined, kind, scientifically trained young woman, who will undertake to carry the mite of humanity through its first year and see it safely started on the difficult journey of life. Training may be had at the Babies' Hospital, Lexington avenue, New York. The course is six months, and the graduate, if competent and a desirable person, can readily find occupation in a home of wealth at a salary of $30 to $50 a month. Her duties are to take charge of the child day and night, but she often has the assistance of a nurse girl and is not called upon to do any housework or sewing.

Teaching as an occupation for woman is so well known that little need be said of its pleasures, pains, or emoluments. Especial training for the work is now almost universally required, and there are numerous normal schools which furnish free instruction with board and other necessary expenses at reasonable rates. The course varies from two to four years.

The average wage of the public school teacher is $40 per month for a school year of nine months or less. Three hundred and sixty dollars a year is not a munificent sum with which to meet the requirements of a woman of intelligence and culture, but teachers of the higher branches, and in city schools, are well paid. In this line of work, as in any, it pays to be a specialist, teaching only one or two branches, as music or drawing. A special teacher usually serves several schools yet carries less responsibility and encounters fewer annoyances than a teacher who has entire charge of one school.

Kindergarten teaching requires special training and commands a somewhat larger salary than regular grade teaching. This is pleasant work for enthusiastic lovers of children and no others have any moral right to attempt it. Private kindergarten schools are numer-

ous and a winsome, refined teacher can gather a class in almost any community. Nearly all normal schools and teachers' training schools have a kindergarten department.

Physical Culture. There is a growing demand for teachers of gymnastics and physical culture. The requirements are a fine natural figure, a thorough knowledge of anatomy and physiology, and the ability to make practical application of the knowledge. Aside from positions in public and private schools open to such teachers, independent work can be secured in almost any town by an attractive teacher who has the knack of getting people enthusiastic over her fad and who makes her classes enjoy themselves under her instruction. One hundred dollars a month is not an unusual salary for a good teacher in physical training, and the opportunities are on the increase.

The Emerson College of Oratory, Boston, Mass., is a school of high standing which has a normal course for training instructors of physical culture. The full course is three years, the tuition $135 a year, while from $150 to $200 must be allowed for board and incidentals. Many of the regular state normal schools include physical training in their course, tuition free.

Cookery. Cooking clubs have become so much of a fad that skilled teachers find it easy to secure private classes, and, as cooking is becoming more and more common as a branch of study in the public schools and in educational institutions for women, there is a growing field for teachers. A year's course in the normal department of the New York Cooking School costs $50 for tuition, but a diploma from such an institution is a great aid to the would-be teacher in securing a position.

Music. The requisite for success in the world of music is the natural gift, without which no amount of training will avail, and there must be added to this years of study and patient practice, be-

ginning in childhood or youth. Every village has its music teacher, who imparts the rudiments of piano playing, and its singing master, who teaches how to "sing by note." Beyond this there is hardly any limit to the instruction one may receive or the amount it may cost.

Nearly all colleges for women offer the best of facilities for the serious study of music, either as a special course or in connection with other studies, and there are schools which are entirely devoted to the teaching of all classes of music and to the training of teachers. One of the best known of these is the New England Conservatory of Music, Boston, which offers especial advantages to lady students.

The teaching of the various branches of music gives a livelihood to many women, both as instructors in public and private schools and as independent teachers. The salaries of teachers in the schools range from $300 to $1200 a year, while private teachers can command all the way from 50 cents to $5 a lesson, the ordinary price being about $1 a lesson. Trained singers with good voices can readily obtain positions in church quartets at salaries of from $150 to $1200 a year, two or three hundred dollars being considered a fair price.

Piano Tuning. A woman who is physically strong and who has a correct ear can readily become a skillful piano tuner, and it is a field of work not overcrowded. The usual charge for tuning a square or upright piano is $2, a parlor grand $2.50.

The New England Conservatory of Music, Boston, offers a two years' course in piano tuning at a tuition of $100 a year.

Literature is a field in which a few women find fortunes, a large number make a comfortable living, a larger number eke out a bare subsistence, but in which the largest number of aspirants waste time and lose money. If a woman feels the fires of genius burning within her soul she *will* write in spite of every discouragement, and if she

is persistent her work will finally secure recognition. Ease of expression is natural to the gentler sex and almost any woman of education and culture can write passably well regarding any subject of which she has positive knowledge, but she should not mistake this facility for the talent which would be her only warrant in turning to literature as a means of livelihood.

Journalism demands less than the higher forms of literature and offers a good field for women of wide intelligence, who have a bright, original way of putting things, and the knack of rapid composition. An experienced writer can command from $15 to $35 a week in newspaper work, according to her ability and her success in securing positions of importance. She must expect to work her way and make a place for herself.

Reporting, the first step in the career of a newspaper writer, is often disagreeable work, and while there are many beginners in this school of experience, there are comparatively few graduates. Still the difficulties are no greater than those in the way of success in almost any calling which commands equal remuneration.

Lecturers. The twenty years following the Civil War in America was a harvest time for lecturers. Those who have been fortunate enough to hear Lucy Stone, Anna Dickinson, Mary A. Livermore, and Julia Ward Howe can but regret that their places seem to go unfilled and that the popular lecturer is no longer in demand and seldom attracts except as subordinate to a stereopticon. However, in these days when a little knowledge of many subjects is fashionable, there is a new field for educated, cultured women as drawing-room lecturers. Women who have little time or inclination for serious study or reading are glad to pay a clever woman who has the knack of making herself entertaining to talk to them once a week on art, literature, architecture, or some other heavy subject, thus taking sugar-coated pills of knowledge in homeopathic doses.

This is a suitable field for the college graduate or specialist who has good references and a little social backing. Several weekly classes of ten or more each may be formed at prices ranging from 50 cents to $1 per lecture, and thus afford the lecturer a very fair recompense for her time and knowledge.

The Stage. It is the general verdict that the stage is a poor place for a woman who can be reasonably contented elsewhere, and unless a girl is very sure that she is a Mary Anderson or a Maxine Elliott in genius, beauty, and character, she would better look elsewhere for a means of livelihood.

The Academy of Dramatic Arts, New York, and other dramatic schools in large cities, train neophytes to act the simpler parts upon the stage in from six months to two years, according to the aptitude of the pupil. The cost of preparation ranges from $600 to $1500, including board. Of course, star actresses can command their own prices and many have become wealthy. Actresses in subordinate parts receive from $12 to $35 a week, but the season is brief at best and employment uncertain, while expenses are necessarily heavy.

Librarians. The office of librarian is in the line of woman's tastes and strength and is fairly lucrative. Most of the smaller libraries are managed by women, while hundreds are employed as attendants in the large libraries. Until within a few years the duties of librarian could be learned only by apprenticeship in a library, but now there are several recognized schools for the training of librarians and assistants. The usual course is two years, and tuition about $75 a year. A graduate from such a school can usually secure employment at from $40 to $50 a month at the start, while promotion comes, as elsewhere, by a combination of ability and fortunate circumstances. A pleasing manner and a genuine desire to be accommodating are indispensable to real success in this work, as well as a love for books, general intelligence, a good memory, and a faculty for being painstaking.

There are library schools in connection with the University of the State of New York, Albany, N. Y., Pratt Institute, Brooklyn, N. Y., Drexel Institute, Philadelphia, and the University of Illinois, Champaign, Ill.

Saleswomen. Despite the hard, tiresome work, long hours, and small wages, the supply of this kind of labor is always far in excess of the demand. Beginners receive but $2 or $3 a week, while $8 to $10 is large pay for any excepting those, who, after years of experience, are promoted to the position of head of department. The greatest prize the sales girl has to hope for is the position of buyer. An expert woman buyer for a large store sometimes commands a salary of $2000 a year or more, with a yearly trip to Europe (on business) thrown in. Such a position demands great shrewdness, foresight, and business ability, and can be attained by only the few.

Compositors. A few years ago the majority of compositors were women. Now a woman has little chance of employment in any of the large printing establishments unless she belongs to "the Union." As a member of the union she receives the same pay as a man, but she is not at liberty to accept less even if it should be to her advantage to do so, and on the basis of equal pay men are preferred because they are strong enough to do the incidental lifting and other heavy work, while a woman must be waited upon more or less. Many of the smaller offices, however, employ compositors without regard to union requirements, and with such it is a question of skill and wages. A good compositor can earn from $8 to $10 per week of 54 hours. A woman who can run a linotype machine with speed and accuracy and accomplish her set task day in and day out may receive from $15 to $18 a week.

PRESS FEEDER.

The Proof reader must have a thorough knowledge of the English language, and the ability acquired by practice to read the printed page rapidly and see all typographical and other errors. The work commands remuneration in direct proportion to the skill of the reader. A good text-book on the subject will give the technical knowledge necessary but only experience in a printing office will bring the practical knowledge that will command a good salary. There is no better way to learn the art than to get the opportunity to serve an apprenticeship in a printing office of good standing, depending for advancement upon the ability to become increasingly useful. The best proof readers are familiar with several languages besides English, possess a great fund of general information, and have a practical knowledge of typesetting. Skilled proof readers receive from $18 to $35 a week.

A course in proof reading is offered by the Heffley School, Brooklyn, N. Y., covering ten weeks, at a tuition of $25.

Clerical work, including bookkeeping, stenography, and copying, furnishes employment to a larger number of educated women than any other calling except teaching. Schools for the teaching of commercial branches abound, and private instruction may easily be obtained. Many who enroll as students fail to complete the course and secure and hold positions, and yet there are many more applicants than positions. There will always be a place, however, for those who can do a common thing uncommonly well.

Tuition in the average business college is $10 to $12 a month for a year of seven to nine months, books and stationery extra. In many cities the Young Woman's Christian Association has classes in these branches, as do also the public evening schools, and instruction free or at nominal rates is furnished at the great industrial schools already mentioned.

Unless a girl is naturally quick at figures and has a taste for them

she is only heaping up sorrows for herself by the study of bookkeeping. This work is for those naturally exact and orderly and for whom long columns of figures have little terror. Wages range from $6 to $18 a week, according to the requirements of the position and the ability of the incumbent.

By means of the sister industries of stenography and typewriting many a woman supplies herself with the necessities of life and a few of its luxuries. To become a superior stenographer, a girl should be naturally alert of mind and quick of motion and should be thoroughly grounded in spelling, punctuation, composition, and if she also has some knowledge of foreign languages, so much the better. The public stenographer, private secretary, and even the office assistant will find use for her entire stock of knowledge and general information, and at best abundant occasion to lament her limitations. The stenographer who combines skill, intelligence, and business sense with an even temper, and who takes a genuine interest in her work, will sooner or later win substantial recognition. The wages of office stenographers who carry little business responsibility range from $6 to $10 a week, while a knowledge of the business gained by experience, with the ability to carry responsibility and direct the work of others, brings from $12 to $20 a week.

Many women maintain offices of their own and the most successful of them earn far more than if on salary in a business office. Average prices are five cents per hundred words for copying manuscript; $1 an hour for taking and transcribing dictation; writing letters from dictation from 10 cents upward per letter, according to length. Some public stenographers make a specialty of going to the homes of women patrons, taking dictation of personal correspondence, and writing it out on fine stationery in a modish hand; $2 per hour is ordinary pay for such work, but there is little opportunity for it outside of large cities. There is occasionally a

stenographer who works for two or three small concerns having but little correspondence each, dividing her time among them by mutual agreement.

Court stenographers receive $10 a day while on duty, but the work is exceedingly wearing, difficult, and disagreeable, and but few women aspire to the position.

Government Clerkships. Hundreds of women are employed as government clerks in the post offices and in the various departments at Washington, at higher salaries than are paid for the same class of work by private concerns. Appointments are based on civil service examinations. Detailed information as to requirements for the various positions can be obtained from the member of Congress of the district to which the applicant belongs.

Telegraphy. A good telegraph operator must have a quick and accurate ear and a good English education. As in stenography, a knowledge of the principles may be easily acquired, but speed and accuracy come only with long practice. There are schools of telegraphy that assist their graduates in obtaining positions, but the art is oftener learned by private lessons. Cooper Union, New York, gives free tuition. A girl may receive in her first position a salary of $25 a month, which, if she is fortunate, is gradually increased until she arrives at the maximum salary of $50 a month. The use of automatic machinery is lessening the demand for common operators.

Telephone operator is the employment of hundreds of girls and young women, but there are probably ten applicants for every position. Consequently the salaries are kept low, the average being about $6 a week, with the exception of the supervisors, who receive from $10 to $15 a week. The novice is usually put on the night force at a salary of perhaps $3 a week. She is watched and assisted and when competent is transferred to the day force with an

increase of salary. The combinations to be learned are almost endless and they must be made without loss of time. The work requires quickness rather than business ability or education, hence is not very attractive to an intelligent, ambitious girl.

Most telephone stations have substitutes in training, to be called in case of illness or any other emergency, and the vacancies on the regular staff are filled from the substitute class.

Architects. A few women have made a signal success as architects and it appears to be one of the coming professions for the occasional woman who has a natural bent for it, a well-trained mind, and who can give the years of study necessary. Poor work is out of place in this calling if anywhere. Architects claim that a college education, supplemented by a knowledge of mechanical drawing, is none too good an equipment with which to begin the study of architecture. A four years' course in a technical school, or two years' study in an architect's office and two or three years in a good technical school, is necessary before a student can command a fair salary as assistant, and then a year or two of hard work before attempting to go into the business for herself. Architects usually receive 5 per cent. of the cost of a building for designs and superintending the construction. Draughting commands from $12 to $30 a week.

The New York School of Applied Design offers a course in architecture to women, as does also the Drexel Institute in Philadelphia. One hundred dollars a year will cover tuition and the other expenses are the usual ones of living.

Decorative Arts. Stand for a moment upon the corner of a city street or go through a department store, and try to count the number of designs that meet the eye. They range from the wrapper on a cake of soap to the ornamental façade of a modern business palace. The cry is always for something novel, and many new designs come year by year from the fertile brains of women.

Designing of all kinds, illustrating, pictorial and practical, china painting, wood carving, glass working, engraving, and kindred arts, all give more or less profitable employment to women. There are art schools in the large cities, such as the New York School of Applied Design, already mentioned, and Cooper, Pratt, and Drexel Institutes, where instruction is given in these various branches of art, and students aided in obtaining a market for their work. It may take ten years of study and practice, even when the artistic gift is combined with a touch of inventive genius, to place the student of the higher forms of art in a remunerative position, but for one who loves the work there is some recompense in the doing.

Photography. Some of the most skillful photographers in the world are now women, and women are employed almost exclusively to do the mechanical work incident to photography. The wages of women employed in photograph galleries range from $5 to $18, or more a week. It seems almost ideal employment for women of intelligence and artistic sense but unfortunately there is room for only a limited number. The art of photography may be learned at Cooper Institute, New York (tuition free), and at some other art schools, but the usual method is to seek instruction from a practical photographer. In these days of amateur photography, developing and printing for amateurs furnishes not a little employment, and it is work that might be done by a woman at her home with a comparatively inexpensive equipment.

Women photographers are especially successful in "taking" children and some make it their entire business to go to the homes for the purpose of photographing the children in home surroundings.

Millinery. The principles of this trade can be learned in an industrial school but nothing short of months of practice will enable the learner to do salable work, and apprenticeship is the most practical method. The term of apprenticeship required is usually sixteen

weeks, divided between two seasons, and many milliners charge for instruction. Wages vary from $5 to $6 a week for "makers" to $15 upward a week for "trimmers." The position of head trimmer in some of the largest establishments is a very lucrative one, sometimes commanding as much as $50 a week, with a yearly trip to Paris for styles included, but such possibilities are for the talented few. One serious drawback to this trade is that the ordinary milliner can hardly escape serious overwork in the "season," and that she cannot depend upon more than seven months' employment in the year. The millinery business has proved attractive to the business woman and many successful millinery shops are owned and managed by women. The profits on all lines of millinery goods are large, but it should be remembered that in a comparatively few weeks of the year enough must be cleared to cover the expenses of the entire year, pay interest on the money invested, and yield the equivalent of a good salary.

Dressmaking is fast becoming one of the fine arts, and the modern dressmaker in order to excel must be a combination of artist, designer, and tailor, while her prices may be almost anything she chooses to make them. Her assistants receive from $4 to $15 a week, according to skill and the kind of work allotted to them.

The elements of dressmaking can be learned at industrial schools and by private lessons, but months of practice must usually precede living wages.

Demonstrating. The demand for effective methods of advertising has opened a new occupation for women. Manufacturers of food products, toilet preparations, household devices, and some other goods, employ women to travel from city to city and store to store to *demonstrate* the practical worth of their goods by well known methods. A competent demonstrator receives from $8 to $15 a week with payment of board and traveling expenses. A life of continuous travel

is not ideal for a home-loving woman, but the work is not exceptionally arduous and the pay good. In most lines of demonstrating women from 30 to 50 years of age can succeed better than mere girls for obvious reasons.

Toilet Expert. Facial massage, manicuring, hair dressing, and allied industries are yearly winning more patrons and give employment to an increasing number of women who act as ladies' maids to the public. A woman with a thorough knowledge of one or more of these industries, who is pleasing in personal appearance and agreeable in manner, need have little difficulty in finding work at living prices, either as assistant in toilet parlors or working independently. The only way to become thoroughly proficient is by apprenticeship, and advertised "schools" that promise to teach the complete art in a few weeks for a large consideration should be shunned. The novice must usually give her time for a year and pay for her instruction besides. Of course any single branch of the business, as manicuring or hair dressing, can be mastered in less time. Prosperous establishments of this kind are to be found in every city, also women who do the work in their homes or go by appointment to the homes of their patrons. The best work can be done at the regular places of business, where are found electrical and other useful appliances that cannot be carried from house to house. Experts in the large cities command high prices, but the following is an average schedule: Cleansing the hair and scalp, including a simple dressing of the hair, 50 cents to $1; dressing the hair elaborately, 35 cents to 75 cents; chiropody, 50 cents to 75 cents per treatment; facial massage, 75 cents to $1 per treatment.

Additional profits may be made by the manufacture and sale of toilet preparations.

Soliciting. There are few occupations that bring good financial returns without a considerable expenditure of time and money in

preparation, but success in soliciting depends more upon the natural ability of the solicitor than upon experience, and an investment of capital varying from one to ten dollars is sufficient to start an intelligent, well-bred woman in an independent and often lucrative business. A good address, self-possession, and pleasing ways are all advantageous, yet there is many a born saleswoman lacking these qualifications who makes up for them by earnestness. A moderately successful solicitor can earn from $15 to $20 a week, working seven or eight hours a day. Usually located for several weeks in a place, her traveling expenses are not heavy. Application to any reputable house selling goods through agents will bring prompt and full information. Many a woman suddenly thrown on her own resources with immediate self support a necessity, has not only supported herself but educated her children by this means. As the writer of a valuable book or the inventor of a useful article is considered worthy of honor, so those who distribute such goods among the people command respect. Unfortunately, more or less worthless merchandise has been foisted upon the public in this way, but it has also been the medium of sale of most of the encyclopedias, art books, and other choice publications.

Life Insurance. For every woman who is self-dependent, or who has others dependent upon her, "to insure or not to insure" is as live a question as for a man in similar circumstances. Endowment policies, combining the features of insurance and saving, are popular with women who wish to lay by something for a rainy day and at the same time provide for a loved one in case of death, and this class are more easily approached and influenced to insure by another woman than by a man. There are also numbers of well-to-do women in the homes who might be induced to insure in favor of their children or of some charitable work in which they are interested. Life insurance offers a good field for an intelligent, energetic

woman; a field not overcrowded and one from which she will not be pushed when her locks begin to turn gray. It is not difficult to secure a contract with a reliable company on a generous commission basis, and the writing of one or two policies a week, as they average, will bring the agent a comfortable living.

Household Industries—a new and appropriate title for the old-fashioned "housework"—are coming more and more to be recognized as of great importance and worthy careful study. It is now possible, if one has the price to pay, to secure as housemaids intelligent young women who have received scientific training in cookery and the care of a house. Such courses as are offered at the Boston School of Housekeeping and also by Cooper Institute and similar institutions, are putting the necessary work of the home on the plane of skilled labor, making it possible for an intelligent, self-respecting young woman who prefers to work in a home rather than in a factory or shop to do so without loss of dignity, and at the same time have a comfortable home, no expenses, and a salary of at least $20 a month.

Home Occupations. Hundreds of women are anxiously looking for work by which they can earn money without leaving their homes. For such the field is narrow, but the time-honored business of "taking boarders" will always be with us and many a woman thereby keeps her home and makes her home keep her. The boarding-mistress who has a well-kept, tasteful, and cheery house, who gives now and then some little comfort or accommodation "not nominated in the bond" and who offers wholesome, appetizing food, seldom lacks patronage. Tact and sound judgment in buying are most desirable qualifications in order to, first, win the boarders, and then to make money out of them.

Dressmaking can be carried on advantageously in the home, and the woman who can make a stylish gown and will accept a moderate price for her work will have little difficulty in securing patronage.

Home bakeries are not so profitable as once because of the great improvement in baker's food of all kinds, but a woman who excels in some one kind of difficult or fancy cooking can oftentimes work up a sale for her specialty through the local grocery, the woman's exchange, by personal solicitation, or advertising.

Women living on farms or small places near cities have earned money by market-gardening, floriculture, the raising of small fruits, and by the keeping of poultry or bees.

Those who can do almost any one thing uncommonly well can usually secure pupils, and women give home lessons in almost every imaginable kind of work.

Factory Workers. Nearly one fourth of all the women engaged in gainful occupations work in factories. The following are representative weekly wages:—

Awnings, tents, and flags, $4 to $12 a week; cotton bagging, $4 to $10 a week; boots and shoes, $4.50 to $24 a week; paper boxes, $5 to $13 a week; cotton goods,—spinners, $3 to $6, weavers, $3.75 to $12; woolen goods—spinners, $3.60 to $6.50, weavers, $3.25 to $11; silk weavers, $3.20 to $15.

These are a few of the common industries. They are all learned by apprenticeship, payment is usually by the piece, and the wide range in wages for the same kind of work is due to the difference between skilled and unskilled labor and in individual productive capacity.

Preparation. The acquired ability to do some one thing well, which is the result of special preparation, is becoming more and more essential. This problem of preparation, calling for both time and money, is a difficult one for the girl to face to whom immediate self-support is a necessity. While the most thorough and satisfactory method of preparation is to attend a special school, fortunately there are ways by which an ambitious, determined girl may fit herself for a gainful occupation

either while at home or at work. Oftentimes she can secure instruction from a competent person in her home town. Again, systems for teaching by mail have been so highly developed as to include nearly all branches of knowledge, and this method is to be commended to those who cannot secure personal instruction or who cannot afford to pay for it. Some of the best correspondence schools furnish competent instruction at low cost with text-books that are marvels of simplicity and clearness. This method throws the learner largely upon her own resources from the start, which compels thoughtful work and develops self-reliance.

Those of limited means who wish to attend art or industrial schools can inform themselves as to the opportunities offered by the great endowed institutions by reference to the volume "Education in the Industrial and Fine Arts in the United States," Part 3d, a deeply interesting book, although a government document, to be found in any public library. It gives a detailed account of the institutes in the United States, established for the purpose of aiding young men and women in developing their latent ability and gaining thereby comfortable self-support.

All admit that woman's noblest employment, when worthily carried, is that of mother and home maker, the nurturer of childhood and the guide of youth. If it is important that no woman assume such high responsibilities with any but high motives, and never chiefly for the sake of a subsistence, then should not every girl be trained for that self-dependence which alone will enable her to exercise the freedom of choice which should be her right?

Effort is the measure of development. If "From him that hath not shall be taken even that which he hath" is a calm statement of the inexorable law of unused talents, then in considering an occupation a woman should remember that while it is always fine in her to do what she has to do well it may not be fine in her to choose the

easier task for the sake of the negative satisfaction of escaping responsibility. It has been the ambitious, courageous woman, who has not feared to step out of the beaten path, who has cleared the way for others to follow in comfort and safety.

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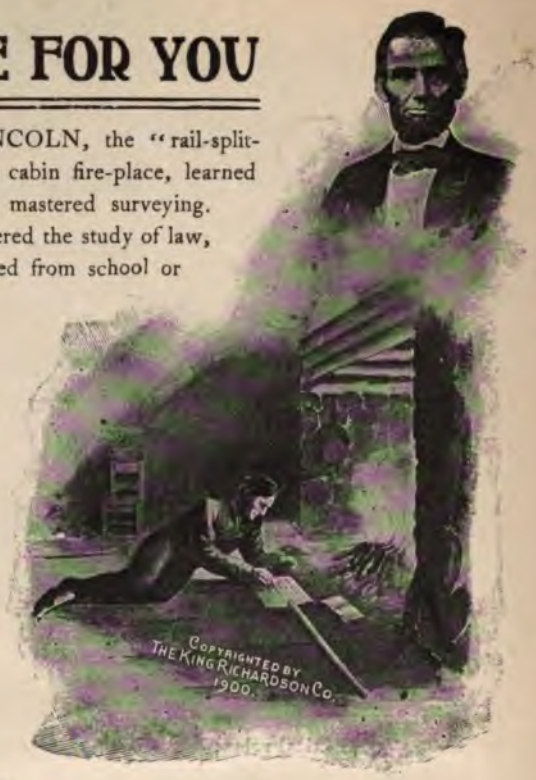

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